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COOPERATIVE MINE DRAINAGE STUDY.
SELECTED AREAS IN THE CLARION RIVER
BASIN

Environmental Protection Agency
Wheeling, West Virginia

June 1971

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COOPERATIVE MINE DRAINAGE STUDY
SELECTED AREAS IN THE CLARION RIVER BASIN

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JUNE, 1971

Prepared By:
Environmental Protection Agency
Office of Water Programs
Wheeling, West Virginia

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SUMMARY

Each of the six inventoried watersheds of the Clarion River basin experience the widespread problem of coal mine drainage pollution. Various measures are needed to reverse the water quality degradation that has occurred in the six watershed areas. For the protection of legitimate water uses and to insure adequate future potential, these measures are needed to reduce concentrations of acidity, hardness, sulfate, iron, manganese, reduce excessive salinity, control sedimentation and high turbidity, and improve aesthetic conditions. A brief summary of each watershed follows:

Toby Creek (Elk and Jefferson Counties)

An estimated 250 mining sites and approximately 2,700 acres of surface mined land were investigated in this watershed. A total of 122 mine discharges contributed a total effluent of 14.7 million gallons per day (mgd). The total acid load discharged to Toby Creek and its tributaries was 37,408 lb/day. Twelve mine drainage sources are identified as principal watershed pollution sources. The combined acid load of these 12 sources was approximately 80 percent of total watershed acid load.

Deer Creek

In addition to mine discharges the Deer Creek watershed has the additional pollution problem of abandoned gas wells whose effluents exhibit chemical characteristics similar to those of mine drainage. The total net acid load discharged by all sources in the Deer Creek watershed was 10,711 lb/day. Thirteen principal sources were identified as major pollution sources. These sites contributed about 81 percent of the total acid load measured in the Deer Creek watershed.

Licking Creek

The largest single source of acid pollution in the Licking Creek watershed resulted from an abandoned gas well effluent in the community of Sligo. Approximately 200 mining sites and an estimated 4,000 acres of surface mined land were investigated in this watershed. The total net acid load discharged by the 143 draining sources was 6,314 lb/day. Sixteen principal pollution sources contributed about 70 percent of the total acid load measured in the watershed.

Mill Creek

The Mill Creek watershed had experienced only limited mining activity. At the time of survey this activity was restricted to surface mine operations. The total net acid load discharged to Mill Creek and its tributaries was 6,947 lb/day. Over 90 percent of this total acid load was contributed by four major sources.

Piney Creek

Approximately 100 mining sites and an estimated 1,800 acres of surface mined land were investigated in the Piney Creek watershed. The total effluent from the 79 sources discharging at the time of inspection was 2.3 mgd. The total net acid load discharged to Piney Creek and its tributaries was 10,941 lb/day. Twenty four sources were identified as principal pollution sources and accounted for 88 percent of the total acid load measured in the watershed.

Toby Creek (Clarion County)

Over eighty sources in the Toby Creek watershed were discharging at the time of inspection. The combined effluent from these sources totalled 3 mgd. The total acid load discharged to Toby Creek and its tributaries was 81,000 lb/day. A single site, Mine No. 1023, contributed an acid load of nearly 50,000 lb/day. There were nineteen principal sources. These sources accounted for 95 percent of the total acid load measured in the Toby Creek watershed.

RECOMMENDATIONS

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Since each of the six inventoried watersheds of the Clarion River is seriously polluted as a result of coal mine discharges, the following recommendations are applicable to all the watersheds in question as well as to any individual watershed. With the apparent exception of the Mill Creek watershed, the remaining five watersheds all contain sources of underground mine drainage, many of which are associated or combined with surface mine operations. Effective drainage control at such sites presents numerous technical difficulties which warrant careful study before a designed program of abatement can be initiated.

There are a number of difficult, lengthy, and expensive tasks involved in any program leading to abatement of pollutant discharges from inactive underground mining sites. A very major problem in this realm is the less than complete technical knowledge available of physical abatement measures. The following recommendations are made for the establishment of an abandoned mine drainage abatement program in the six inventoried watershed of the Clarion River basin. The recommendations are based on the stream water quality measurements performed by the Environmental Protection Agency and the Pennsylvania Department of Environmental Resources during the 1967 cooperative mine drainage survey.

1. Establishment of a mine drainage source abatement priority listing. Such priorities could be assigned utilizing the data outlined in this document. The priorities can be based upon the impact and relative contribution of each source to the total watershed problem. For example, a mine discharging high acidity and/or mineral loadings would be of a higher priority than a discharge of lesser loading located downstream of the discharge of greater pollutant loading. The priority of some sources may change as a result of item 3 below. A preliminary priority listing of principal mine drainage sources is contained under the Pollution Abatement section of each individual watershed report.
2. Feasibility studies. Probably undertaken on a contractual basis, these studies would have the objectives of proposing abatement methods for the individual prioritized sources. Before abatement costs can be estimated each selected mine site would require a detailed investigation. This investigation would require a detailed geological inspection as well as determining the extent of the mined area, the presence of additional openings and the possibility of interconnection with other mines.
3. Characterization of water quality with time. Coincident with the preliminary feasibility studies, a basin wide water

quality sampling network should be established for repetitive water quality measurements. The network should include all important tributary streams receiving mine drainage and a number of locations on the principal streams. The larger mine drainage sources should also be included. Flow measurement and chemical analyses could then be performed at these locations at regular intervals, preferably weekly or biweekly, for a minimum of a 12-month water year.

This phase of the total study will provide data for a pollution source priority listing based on the annual pollution contribution of each source. Also, sufficient stream water quality data will be developed to permit reasonably accurate stream quality improvement predictions from contemplated corrective programs.

4. Detailed engineering plans. Based on items 2 and 3, detailed engineering plans and final cost estimates could then be developed for the most applicable proposal from item 2; that is, most applicable from the standpoint of the greatest water quality improvement to be obtained for a dollar spent.
5. Construction. Installation of appropriate physical measures could then be carried out. Monitoring of discharge changes with time at the altered sites and in the receiving streams must be an integral part of the abatement program. Routine maintenance at the controlled sources is also essential. Easements to or out-right purchase of land may be necessary for the Commonwealth of Pennsylvania to obtain control over pollutant sources on private property. Institutional changes also may need to be sought to enable the state government to achieve site control by the expenditure of public monies on private property. The acquisition of mineral rights in the areas of source abatement projects may be necessary to prevent future mining activity from destroying the physical controls.

All conclusions, recommendations, and estimates contained in this document are subject to refinement as the programs of the EPA and the Commonwealth of Pennsylvania progress.

BACKGROUND

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Streams draining the major mining areas of the Clarion River basin have probably been acidic in nature from the time of the opening of the first mines and they remain so at the present time. A 1943 report of the U. S. Public Health Service which reflected 1940 conditions, reported acid stream conditions in certain tributaries to the Clarion River. ^{1/} The document reported pH values as low as 3.0 at the mouth of Toby Creek (Elk County) and similar values in Elk Creek, near St. Mary's, Pennsylvania.

In the last 25 years a number of published and unpublished reports have described acid stream conditions in this area. None of them, however, were detailed or comprehensive studies of the problem.

During 1966, the Office of Water Programs of the Environmental Protection Agency in Wheeling, West Virginia conducted a stream quality survey of the upper Ohio River basin as part of the overall Appalachia Water Resources Survey. ^{2/} In the Clarion River area, a network of 12 stream sampling stations was established for repetitive sampling and flow measurement during 1966. The survey produced quantitative data on mine drainage problem areas over the drainage basin. The survey findings are discussed in the following section. The location of the Clarion River tributaries inventoried during the mine survey and the location of the 1966 water quality sampling points are shown on Figure 1.

STREAM WATER QUALITY - SURVEY FINDINGS, 1966

The Clarion River was affected by mine drainage over its entire length from the headwaters of the East Branch in McKean County to the Allegheny River in Clarion County. Mine drainage effects are more pronounced in the lower reach of the river downstream of the Clarion-Jefferson County line. The Clarion River discharged an average net acid load of 63 tons per day to the Allegheny River during the survey period. The water quality information obtained during the 1966 survey is shown in Appendix A.

The East Branch Clarion River watershed was polluted by mine drainage. At Station No. 522 below the East Branch Reservoir, the pH ranged from 5.5 to 6.6 and acidity concentrations consistently exceeded alkalinity concentrations. The net acid load at this point was 4.0 tons per day.

The Clarion River receives only minor mine drainage contributions below East Branch to the confluence of Toby Creek, southwest of Ridgway in Elk County. During the sampling period, Toby Creek discharged

7.1 tons per day of acidity to the Clarion River and had a pH range of 3.6 to 4.1. Alkaline values were zero on each sampling occasion at Station No. 518. The principal tributary to Toby Creek, Little Toby Creek, drains a once-important mining area and is the main source of mine acid in the Toby Creek watershed. Its acid load during the study period was 8.4 tons per day (Station No. 519). About one ton of equivalent acid was neutralized by natural stream alkalinity in the mainstem of Toby Creek.

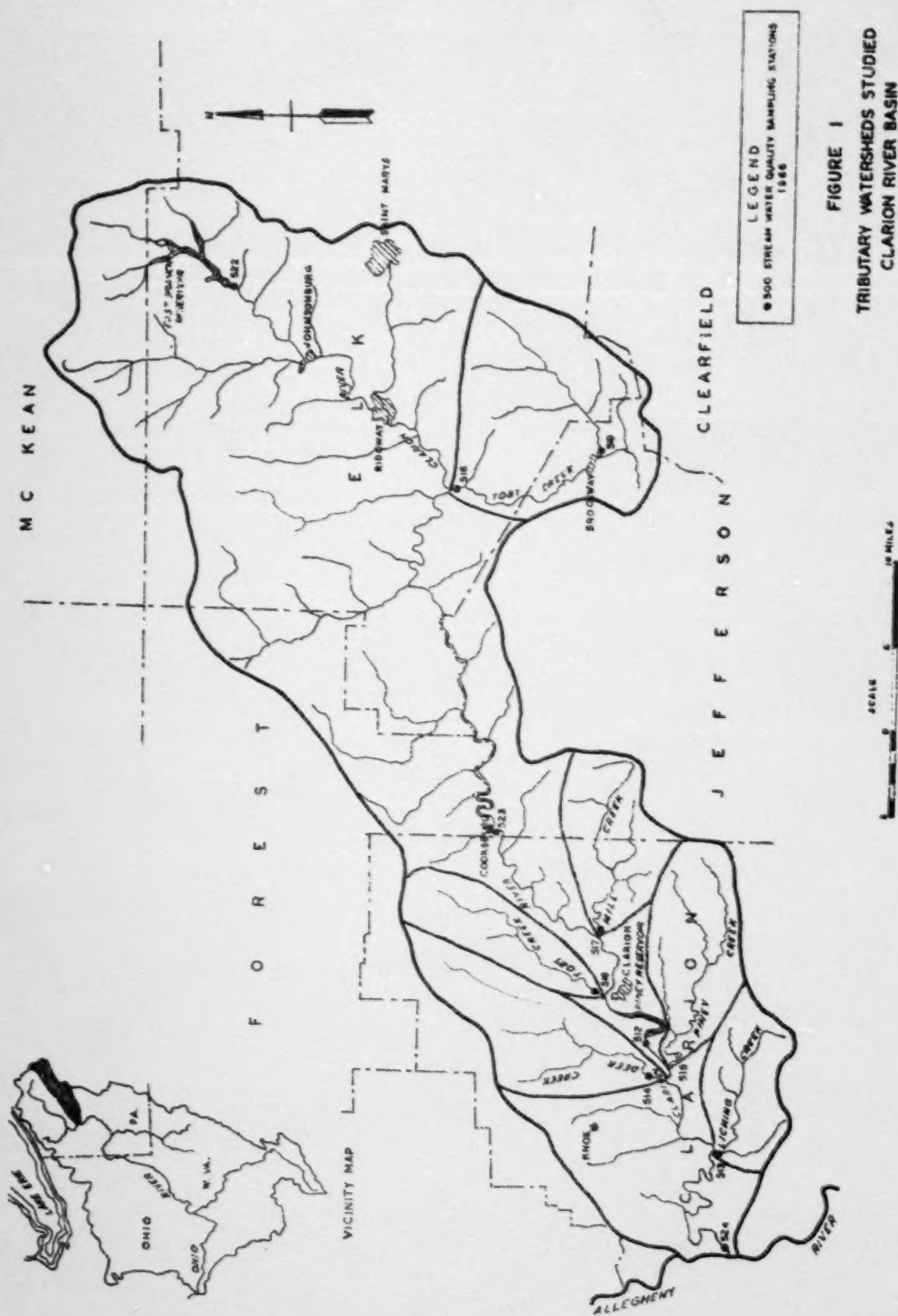
At Station 512, Clarion River below Piney Reservoir, the acid load was only 3.0 tons per day. However, acidity consistently exceeded alkalinity and the pH was as low as 4.4.

Very little mine drainage enters the Clarion River between Toby Creek (Elk County) and Station No. 523 near Cooksburg, Pennsylvania. At this location the average net acid load for the survey period was zero but acidity concentrations exceeded alkalinity one-third of the time. The pH at this point ranged from 5.7 to 6.7. On the average, alkaline and acid values were essentially equal.

In the reach of the Clarion River from the city of Clarion to the mouth, an aggregate of about 58 tons per day of acidity was received during the survey by the river from five acid tributaries. These tributaries and their chemical characteristics are listed in the following table:

<u>Tributary</u>	<u>Station No.</u>	<u>pH Range</u>	<u>Net Acidity</u>	
			<u>mg/l</u>	<u>(tons/day)</u>
Mill Creek	517	2.9-3.2	187	8.5
Toby Creek	516	2.8-3.1	735	24.0
Piney Creek	515	3.4-4.0	72	10.0
Deer Creek	514	3.2-3.4	101	7.0
Licking Creek	513	2.6-3.1	294	8.4
TOTAL				57.9

The Clarion River at mouth exhibited pH values from 4.1 to 5.3, contained acidity concentrations from 25 to 40 milligrams per liter, and discharged an average net acid load of 63 tons per day. The maximum alkalinity concentration present during the study was 4 mg/l. The net acidity of the river near Cooksburg, Pennsylvania was about zero, therefore, the 63 tons per day loading at the mouth was mainly due to the inflow of the five acid tributaries named in the above tabulation. Over 90 percent of the residual acid load in the Clarion River at mouth comes from this small area.



INTRODUCTION

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In the spring of 1967 several discussions were held between personnel of the Office of Water Programs, Environmental Protection Agency, Wheeling, West Virginia and personnel of the Pennsylvania Department of Environmental Resources. These discussions developed into a cooperative State-Federal project to locate and quantify all significant sources of coal mine drainage in the principal problem areas of the Clarion River basin. Based on available stream quality data, the problem areas scheduled for detailed investigation were the drainage areas of the major acid contributing tributaries of the Clarion River. Pertinent data regarding the defined problem areas is given in the following table. The respective locations of the surveyed watersheds in the Clarion River basin are shown on Figure 1.

PRINCIPAL MINE DRAINAGE PROBLEM AREAS
CLARION RIVER BASIN

<u>Problem Area</u>	<u>Clarion River Mile Point</u>	<u>Drainage Area (sq. mi.)</u>	<u>Net Acid Load</u>	
			<u>(lb/day)</u>	<u>(lb/day/sq.mi.)</u>
Toby Creek watershed (Clarion County)	30.0	37	47,582	1,286
Piney Creek watershed	21.6	70	19,272	275
Mill Creek watershed	35.0	56	16,960	303
Licking Creek watershed	14.8	52	16,850	324
Toby Creek watershed (Elk & Jefferson Counties)	80.2	152	14,936	119
Deer Creek watershed	21.3	<u>69</u>	<u>13,845</u>	<u>201</u>
TOTALS		409	129,445	----

Four two-man crews performed the field work during the study. Although the number of crews working at one time ranged from two to four due to other work commitments, the total field force was in operation at least on-half of the study period. The field study began the middle of May 1967 and was completed the first week of October 1967.

Field crew personnel were supplied on an equal basis by the EPA and the Commonwealth of Pennsylvania, i.e., four men each. The EPA personnel were all from the Office of Water Programs, Wheeling, West Virginia. The Pennsylvania personnel were from the Department of Environmental Resources Regional Offices at Pittsburgh, Meadville, and Williamsport, Pennsylvania. Generally, two crews were assigned to each tributary watershed studied and two watersheds were studied at the same time. Mine discharges were numbered consecutively by watershed, as encountered. Field personnel prepared an inventory

sheet for each sample taken describing the conditions found. Color photographs were taken frequently to augment the description. Field operations were under the direction of the Wheeling Office.

Samples were taken for laboratory analysis of each mine discharge and selected surface streams. Conductivity and pH determinations and a flow measurement were made at the time of each sample collection. The samples were analyzed by laboratory facilities in the Wheeling Office of Water Programs for additional parameters of total acidity, alkalinity, hardness, sulfate, total iron, and manganese. Some 700 samples were analyzed during the four-month intensive sampling period.

In the past several years Pennsylvania has shown an increasing awareness of stream pollution resulting from the discharges of both active and abandoned coal mines. In 1965 Pennsylvania amended the Clean Streams Law for pollution control from active mines.^{3/} In 1967 a Land and Water Conservation and Reclamation Bond Issue of 500 million dollars was approved. This bond issue allocated 150 million dollars for the abatement of mine drainage pollution from abandoned mines. The bond issue money is budgeted over a ten year period under the direction of the Department of Environmental Resources. In conjunction with the Clean Streams Law, the Commonwealth is in the position to direct pollution abatement activities toward the abandoned mine problem and also in the position to enforce effluent standards on the discharges emanating from active coal mines.

Present Commonwealth of Pennsylvania mine drainage pollution control regulatory authority is adequate to prevent additional stream quality degradation due to iron and acidity as a result of active or future mining activities. Stream pollution resulting from operating coal mines and related facilities in the Clarion River basin are relatively minor. It is the residual problem of drainage from abandoned mines that will require virtually all the emphasis of any designed program of drainage abatement in the Clarion River basin.

The Commonwealth has developed their abandoned mine drainage program in four phases.^{4/} The initial field inventory and documentation of existing pollution sources, as presented in this document, completes the Phase I (Pollution Source Inventory) portion of this program. Phase II (Engineering Studies and Plans) essentially incorporates the recommendations outlined in items 2, 3, and 4 as listed in an earlier section of this document. Phase III of this program includes construction while Phase IV is concerned with operation and maintenance of the physical structures.

As mentioned above, the mine drainage source inventory conducted during the cooperative study completes the Phase I portion of the abatement schedule. At the present time Pennsylvania has initiated preliminary engineering studies (Phase II) and/or on a limited basis, construction (Phase III) in at least two of the six inventoried Clarion River watersheds. These areas include the Mill Creek and Toby Creek (Elk and Jefferson Counties) watersheds.

The purpose of this report is to provide basic data concerning sources of coal mine drainage in critical problem areas of the Clarion River basin. Information regarding the location, physical characteristics, and quantity and quality of point sources is requisite to the development of a program to reduce or eliminate the deleterious water quality affects of mine drainage.

The objectives of this report are to;

1. Describe the significance and impact of water quality impairment by coal mine drainage in the Clarion River basin,
2. Identify and characterize the tributary watersheds contributing significant amounts of acidity and related constituents to the Clarion River.
3. Relate mine drainage contributions of sub-watersheds to the mainstem of the receiving stream.
4. Inventory the sources of coal mine drainage, by watershed, in terms of salient characteristics and quantity and quality of discharge,
5. Isolate and identify the principal polluting sources in each watershed unit studied.
6. Outline essential steps in a mine drainage abatement program. Descriptions of the six inventoried watersheds of the Clarion River basin are contained in the following sections of this document. There are six separate sections, one pertaining to each watershed. Each section contains its own summary and conclusions, maps, water quality data, and related mine drainage information.

Abating pollution from inactive mines is a task the cost and success of which are difficult to predict at this time with reasonable accuracy. The difficulty stems from the fact that there is limited experience with watershed-scale abatement projects upon which to base estimates. For example, it has been variously estimated that mine drainage abatement in the Clarion River basin might range from a minimum of three million dollars for selective source abatement, to a maximum of 60 million dollars for basin-wide abatement.

It is the general conclusion of this report that the development of meaningful cost estimates for the abatement of mine drainage pollution in the Clarion River basin is sufficiently complex to warrant a separate engineering-economic study. No attempt has been made to suggest order-of-magnitude cost estimates for the study area.

A preliminary and relatively short-term survey, such as reported herein, is qualitative but results in limited quantitative conclusions. The chemical loadings of mine drainage parameters measured in the mine discharges and the polluttional effects of these loadings measured in the receiving streams are representative of the time of survey. These load figures do not reflect permanent or established conditions and will exhibit widely varying rates over different periods of hydrologic conditions. The acquired data is significant in that it provides a preliminary basis for further studies. The recommendations leading to an action program of mine drainage pollution abatement stated in this document are based upon this acquired data.

WATERSHED DESCRIPTION

The cooperative mine drainage source investigation included a large part of Clarion County and small parts of Elk and Jefferson Counties. This section of the report will deal with the geology and ground water of those three counties as related to the six tributary watersheds of the Clarion River basin that were studied.

The Clarion River flows to the southwest and drains most of Clarion County and a small portion of eastern Jefferson County and the southwestern part of Elk County. The drainage of the Clarion River basin is 1232 square miles. Of the areas studied, only the upper Toby Creek watershed lies completely outside of Clarion County. The Deer Creek, Licking Creek, Piney Creek, and Toby Creek watersheds are completely within Clarion County. The Mill Creek watershed drains portions of both Clarion and Jefferson Counties. Through much of its course the Clarion River is a meandering stream, flowing in narrow V-shaped valleys, the walls of which rise 400 feet or more above the stream.

There are few extensive areas of flat land within the study area. With the exception of a few small flat areas along some of the streams and small upland flats, the surface of the area consists of sloping ground. The highest elevation occurs in Elk County south of the town of Kersey, where several hilltops reach an altitude of 2,100 feet above sea level. Much of the area has an altitude in excess of 1,500 feet. The lowest part of the study area lies along Licking Creek at an altitude of 960 feet above sea level, where it joins the Clarion River.

GEOLOGY

Unconsolidated Surface Deposits

Jefferson, Clarion and Elk Counties all lie outside the area that was covered by the continental ice sheets. The water produced by the melting of these great ice sheets carried outwash material down some of the streams of Clarion County and partly filled the valleys with silt, sand, and gravel. In contrast, the upper Toby Creek watershed is excluded from this geologic phenomenon since none of the drainage lines carrying water from the melting glaciers crossed this area. In these stream bottoms, thin alluvial deposits are present. The upland areas are mantled by a thin cover of soil that has been produced by the weathering of the underlying bedrock.

Consolidated Rock Formations

The rocks outcropping in the study area in descending order consist of the Conemaugh Formation and Allegheny and Pottsville groups, all of Pennsylvanian Age, and the Burgoon Formation and Pocono Group of Mississippian Age. In Clarion County the Pocono Group is absent

due to an unconformity at the base of the Pennsylvania system. In Elk and Jefferson Counties only the very top of the Pocono system is found along Toby Creek.

The highest rocks exposed extend from about 200 feet above the base of the Conemaugh Formation in Clarion County and 400 feet above the base of the Conemaugh Formation in Elk and Jefferson Counties. The oldest rock unit exposed in the Clarion area is the Burgoon Formation. While the Pocono Group is the oldest exposed rock unit in Elk and Jefferson Counties, the surface rocks in the watershed belong principally to the Allegheny Group. The Conemaugh Formation caps only the higher peaks in Clarion, Elk, and Jefferson Counties and is not abundant because it weathers easily.

The Allegheny Group, predominant throughout the bituminous coal region of western Pennsylvania, contains, the following minable coals in descending order: Upper Freeport, Upper Kittanning, Middle Kittanning, Lower Kittanning, Clarion and Brookville. In various sections throughout the Clarion River watershed, distribution of the Upper Freeport and Brookville beds is irregular or absent due to differences in erosion and deposition.

The Pottsville Group, approximately 200-300 feet in thickness, consists chiefly of sandstone and crops out in all three counties covered in this study. The upper limit of the group is not definite when the Brookville coal is absent. The base of the Group also is indefinite because the Connoquenessing sandstone resembles the Burgoon sandstone appearing in the Clarion County area.

Structure

The rocks of the area are nearly horizontal but dip to the south and southwest 20 to 25 feet to the mile. There are, however, many minor irregularities in this regional dip. The axes of the fold generally trend about N. 40° E. excluding local irregularities. In general, the structural features of this region are poorly defined.

GROUNDWATER OCCURRENCE AND QUALITY

The Clarion River watershed has moderate supplies of ground water obtained from springs and wells. Numerous small springs are utilized where they are favorably located. The yield of most of the small springs and shallow wells varies considerably with the wet and dry seasons. As a result, the wells and springs are not a reliable source of water. The chief problem is acquiring water low in iron.

In many localities, the Pottsville Group consists of massive sandstone containing ample supplies of ground water. The water is generally of fair quality although high in iron salts.

An iron problem rises from a thin layer of iron carbonate or oxide overlying the Vanport limestone. In early days when the ore was utilized in many parts of west Pennsylvania, the name "Ferriferous" was given to this strata. The Vanport limestone, broken by horizontal

and vertical joints, underlies the Upper Freeport coal and in some places rests directly on the Upper Clarion coal. Numerous improperly plugged abandoned oil and gas wells penetrate this formation. The effluents from these wells contribute to the high concentrations of iron in the Deer Creek watershed and other tributaries of the study area. In addition, most of the abandoned mines are now discharging water that is high in iron and acid. The high iron concentrations are directly dependent on ground water movement through the fractured Vanport limestone and associated coal-bearing strata.

COAL MINING

Coal Production

Clarion County is a significant coal producing county of the Commonwealth. At no time has production dropped below one million tons per year. During 1967 the county produced 2.8 million tons. Strip mining is the predominant method employed for the extraction of soft coal in Clarion County. During 1967 underground mines produced only 34,000 tons of the total 2.8 million ton county wide production. 5/

The Clarion and Lower Kittanning seams accounted for most of the coal produced in 1967. Additional seams mined in Clarion County are the Middle and Upper Kittanning.

Coal mining operations in Elk County reached peak production in the years prior to 1952. Since 1952 production has gradually declined. For the period of record, high production was reached in 1952 and 1948 with reported yearly totals of more than one million tons. Total coal production for the period of record in Elk County is about 18.6 million tons. Total production for 1967 was 331 thousand tons from 20 reporting mines. Production was divided between surface and underground mining operations in the ratio of 286 thousand tons to 45 thousand tons, respectively.

In the reported periods Jefferson County has consistently out-produced Elk County. From an all time high of 3 million tons in 1947, gradual declines in production were evident until 1960 when production began a steady increase. At no time has Jefferson County production dropped below one million tons per year. Total county production during the period of record is more than 58 million tons. Production for 1967 was 1.83 million tons from 78 reporting mines. Production was divided between surface and underground mining operations in the ratio of 1.08 million tons to 0.75 million tons respectively.

Coal Reserves

Sufficient coal reserves are present in Clarion County to warrant steady and continued production. Reserves, based upon 50 percent recovery are estimated at more than 750 million tons. The major part of the coal reserves are contained in the Upper Clarion, Lower Clarion, Lower Kittanning, and Brookville seams.

The Lower Kittanning is the most persistent seam thicker than 28 inches. The Lower Clarion and Brookville seams are also present in beds exceeding 28 inches, however, the deposition of these seams is sporadic. The remaining coal reserves are in beds of less than 28 inches which imposes some restriction upon minability.

The Lower Kittanning has proved to be the most economically important coal bed in Elk County and has contributed most of the total county production. In the Toby Creek watershed this coal was extensively mined in the headwaters area, including Dagus and Toby Mines.

Ten minable coal beds are in the county, however most are only mined locally. Mining operations in Elk County during 1967 were active in both the Upper and Lower Kittanning and Upper and Lower Freeport coals.

Irrespective of seam, recoverable coal reserves in Elk County, based on 50 percent recovery, are estimated slightly in excess of 200 million tons.

Jefferson County contains eleven coal beds but the Lower Freeport and Lower Kittanning seams are the most important. Five additional coal beds including Brookville, Clarion, Middle and Upper Kittanning, and Upper Freeport are mined locally. Mining operations throughout the county during 1967 were active in all the above mentioned coal seams.

Irrespective of seam, recoverable coal reserves in Jefferson County, based on 50 percent recovery, are estimated to be about 1,390 million tons.

TOBY CREEK WATERSHED MINE DRAINAGE INVENTORY

ELK AND JEFFERSON COUNTIES

SUMMARY AND CONCLUSIONS

1. The Toby Creek watershed, draining 125 square miles of Elk and Jefferson Counties, Pennsylvania, has been severely degraded as a result of coal mine discharges. Both underground and surface mining are common in the watershed.
2. The degraded water quality of Toby Creek extends the entire length of the main stem as well as affecting many miles of tributary streams. The streams draining the coal field areas are acidic, highly mineralized, and devoid of normal aquatic life.
3. Approximately 250 mining sites and an estimated 2,700 acres of strip mined area were investigated during this study. Samples for chemical analysis were collected from 122 sources discharging at the time of the survey. Discharges from coal mine sources ranged from one to 1,353 gallons per minute (gpm) and totalled 14.7 million gallons per day (mgd). The pH of the effluents ranged from 2.4 to 7.6 and total acidity concentrations as high as 2,370 milligrams per liter (mg/l) were recorded. Only 14 of the 122 discharging sources were alkaline. The total acid load (less alkalinity) discharged to Toby Creek and its tributaries equalled 37,408 lb/day.
4. The only active sources of acid pollution at the time of the survey were 3 drift mines. Underground mines including combination underground mines were the principal source types of acid pollution. These sources were responsible for 95 percent of the acid load measured in the watershed.
5. Twelve mine drainage sources are identified as principal watershed pollution sources. These sources consist of eight drift mines and four combination drift mines. The combined acid load of these 12 sources was 29,831 lb/day, about 80 percent of the total measured acidity.

DESCRIPTION OF AREA

The Toby Creek watershed embraces an area of 125 square miles located in Elk and Jefferson Counties, Pennsylvania. The watershed is U-shaped and about 29 miles in length. Most of the watershed is located in mountainous terrain with elevations commonly exceeding 2,000 feet above sea level. Generally, the valleys are narrow and the hillsides are steep and abrupt. Principal tributaries to Toby Creek are Brandy Camp Creek, Elk County (11.2 square miles) and Rattlesnake

Run Jefferson County (16.5 square miles).

The Toby Creek watershed is bounded on the north by the Clarion River, on the west and south by tributaries to Redbank Creek and on the east by Susquehanna River drainage.

Brockway is the largest community in the watershed with a 1960 population of 2,500. The remaining small communities located throughout the watershed had 1960 populations under 500.

The Toby Creek watershed experienced extensive underground mining activity between 1925 and 1945. Employment in these mines was high, however, production tonnages and the extent of the underground workings were somewhat limited due to the almost total non-mechanization of these mines. This mining was in turn followed by contour strip mining of the coal outcrops along the hillsides. At the time of the survey active mining in the watershed was limited to three, 2-4 man underground operations, restripping, and mountain top area strips, which were working in coal seams of 24 inches or less in thickness.

STREAM WATER QUALITY

The water quality of Toby Creek is seriously degraded over its entire length as a result of coal mine drainage. The water quality effects of mine drainage throughout the watershed are those of excessive iron, sulfate, hardness, and total mineralization in the stream. Although no sources of mine drainage were located downstream of Baghdad Run, the residual effects of the mine drainage are evident over the entire downstream length of Toby Creek.

Limestone Run, Kyler Run, and Brandy Camp Creek are the most severely mine drainage degraded tributaries in the Toby Creek watershed. Approximately 56 percent of the total source acid load measured in the watershed discharged from coal mines located on these three tributaries. Alkalinity concentrations at the mouths of these tributaries were nonexistent while pH ranged from 3.2 to 3.7 and conductivity ranged from 600 to 1,600 units.

Below the confluence of Brandy Camp Creek, Toby Creek received only minor amounts of mine drainage pollution. Irrespective of the extensive mining activity that has occurred on Rattlesnake Run, the small acid increments discharged to the stream are rapidly neutralized. The pH and conductivity values of tributaries to Rattlesnake Run ranged from 6.8 to 7.4 and 50 to 800 micromhos/cm, respectively. Main stem pH values varied from 6.7 to 7.1 and conductivity values varied from 400 to 650 units.

The stretch of main stem Toby Creek below Brockway was characterized by an orange-yellow precipitate in suspension and on the stream bottom. This mixture of ferric hydroxides and/or basic ferric sulfate is often referred to as "yellow-boy" and is common in many streams seriously affected by coal mine drainage.

Six stream sampling stations were located on Toby Creek during the mine drainage source investigation (Table 1). One sample and a flow measurement were obtained at each of these stations. A summary of all stream data is presented in Table 2. Stream data for the 1966 stream survey is also contained in this table.

In conjunction with sampling and flow measurements at selected stream locations, pH and specific conductance determinations were made at a number of additional stream locations in the watershed during the source investigation. These values and the stream sampling locations are shown in Figure 2.

Station No. 1219

Little Toby Creek, above Limestone Run had a pH of 3.5, an acidity concentration of 215 mg/l, and carried an acid load of 2,345 lb/day. Sulfate and iron concentrations at this point were 600 mg/l and 8 mg/l, respectively. Due to the abnormally low pH of Little Toby Creek at this point the iron remained in solution and did not precipitate. In appearance the stream was free flowing and deep scarlet in color with very moderate turbidity.

Station No. 1220

Over 2,600 lb/day of unneutralized residual acid was found at the mouth of Limestone Run. Sulfate and iron loads at the mouth of the tributary were 4,821 lb/day and 115 lb/day, respectively. Concentrations of hardness and manganese were also excessive.

Station No. 1221

The 2.6 square mile drainage area of Kyler Run received a measured source acid load of 8,267 lb/day. A residual load of 5,346 lb/day was found at the mouth of the tributary. The sulfate load exceeded 10,000 lb/day at this station.

Station No. 1222

An acid load of 7,846 lb/day was measured at the mouth of Brandy Camp Creek. The sulfate and iron loads at this station were 19,617 lb/day and 296 lb/day, respectively.

Table 1

Stream water quality sampling stations
Toby Creek Watershed, Elk and Jefferson Counties

Station Number	Sampling Period	Stream	Location
1219	July 1967	Little Toby Creek above Limestone Run	Near Mouth
1220	July 1967	Limestone Run	Near Mouth
1221	July 1967	Kyler Run	Near Mouth
1222	July 1967	Brandy Camp Creek	Near Mouth
1223	July 1967	Little Toby Creek	Near Mouth
1224	July 1967	Toby Creek	Near Mouth
0519	June - August - September, 1966	Little Toby Creek	Near Mouth
0518	June - August - September, 1966	Toby Creek	Near Mouth

Table 2

Stream water quality data, Toby Creek watershed, Elk and Jefferson Counties

Station No. of Number Samples (gpm)	pH	Flow Samples (gpm)	Specific Conductance	Total Acidity		Total Hardness		Sulfate		Total Iron		Manganese	
				mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day
1219	3.5	909	1,150	215	2,345	278	3,032	600	6,544	8.0	85	9.4	103
1220	3.2	410	1,600	540	2,656	327	1,608	980	4,821	23.0	115	22.0	108
1221	3.3	1,188	1,350	375	5,346	280	3,991	705	10,050	13.0	183	9.6	137
1222	3.7	6,539	600	100	7,846	190	14,908	250	19,617	4.0	298	4.6	361
1223	3.8	18,765	625	75	16,888	184	41,433	270	60,798	1.0	315	6.8	1,531
1224	4.1	30,155	450	45	16,283	143	51,745	195	70,562	1.0	434	4.2	1,520
0518 ^{1/}	3.9	12,960	735	125	14,936	271.8	40,154	285.8	34,157	0.8	140	7.8	1,009
0519 ^{1/}	3.2	6,570	1,140	214	16,840	409	28,565	289	31,478	4.3	252	1.8	928

^{1/} Additional sampling of Station Nos. 1223 and 1224, respectively, conducted prior to the mine drainage source investigation.^{2/} Average of 6 samples, 1966.^{3/} Specific conductance measured as micromhos/cm.

Station No.'s 0519, 1223

The next downstream sampling station was located at the mouth of Little Toby Creek near Brockway.

During the 1966 stream sampling survey an average of 16,840 lb/day of acidity was measured at the mouth of Little Toby Creek. (Station No. 0519) This represented the residual acid load which was not neutralized by upstream alkaline tributaries. Approximately 10 tons/day of acid was neutralized. However, the average sulfate load at this same point was more than 15.5 ton/day. This sulfate content is the residual component of the quantities of sulfate salts and sulfuric acid received upstream by mine drainage.

One additional sample was collected at the mouth of Little Toby Creek coincident with the mine drainage source investigation (Station No. 1223). At this time the stream carried an acid load of about 8.5 tons per day.

Station No.'s 0518, 1224

At Station No. 0518, the mouth of Toby Creek, an additional average of 1,900 lb/day of acid load carried by the main stream was neutralized by alkaline water entering this stretch of Toby Creek during the 1966 stream survey. With the decrease in acid load an appropriate increase in the average sulfate load to 34,157 lb/day (Table 2) was also found.

One additional sample was collected from the mouth of Toby Creek during the mine drainage source investigation (Station No. 1224). The acid load carried by the stream at this point was a little over 8 tons per day.

BIOLOGY

A biological evaluation of Toby Creek at Station No.'s 1224 and 0518, Toby Creek near mouth, was conducted during 1966 to determine the effect of pollution conditions upon normal aquatic fauna. The benthic organisms collected consisted almost entirely of acid-tolerant forms. The substrate of the stream was characterized by physical evidence of mine drainage pollution which included red stains on rocks, sediment characteristics, and lack of biological growths.

In summary, all mine-drainage-affected stream locations sampled were characterized by pH values below 4.1 and specific conductance values above 450 micromhos/cm. Alkalinity concentrations were depleted to zero and acidity concentrations ranged from 45 mg/l to 540 mg/l.

Many of the watershed streams draining mined areas were characterized by red appearance and the presence of an orange-yellow precipitate in suspension or on the stream bottom. During periods of high stream runoff, the streams are extremely turbid due to flush-out and resuspension of stream bottom deposits that resulted from drainage of mined areas.

SOURCES OF MINE DRAINAGE

Some 250 mining and related sites and estimated 2,700 acres of strip mined area were investigated during the Toby Creek study. Samples for chemical analysis were collected from 130 potential drainage sources, 122 of which were discharging at the time of the survey. Eight samples were collected from strip mine ponds that had no visible surface effluents. Discharges from the coal mine sources ranged from one to 1,353 gpm and totalled 14.7 mgd. The total acid load (less alkalinity) received by Toby Creek and its tributaries was 18.7 tons per day.

A detailed description of the mine drainage sources in the Toby Creek watershed follows. Pollutant discharges which were categorized as principal sources are described in a later section. All mine sites located in the watershed are shown in Figure 3 at the end of the source description section. Mine drainage data is shown in Appendix B.

Headwaters

The headwaters of Little Toby Creek arise near the community of Coal Hollow and flow southwest toward the community of Challenge. At Challenge, Little Toby Creek is joined by one of its principal tributaries, Brandy Camp Creek. The drainage areas of Brandy Camp Creek and Little Toby Creek above Challenge, represent the two areas in the Toby Creek watershed which were most seriously degraded by mine drainage. All of the twelve principal mine drainage sources were located within these two headwater drainage areas. These two parts of the Toby Creek watershed represent 15 percent of the total 125 square mile drainage area and received more than 90 percent of the total source acid load.

During the field inventory twenty-two abandoned deep mines discharging to Little Toby Creek were located between the headwaters

area and the next downstream tributary, Limestone Run. The acid load discharged to Little Toby Creek in this 1.8 square mile area amounted to more than 4,400 lb/day. The largest single source of mine drainage pollution in this area (Mine No. 960) resulted from an old mine seal. This mine seal discharged an acid load of 1512 lb/day to Little Toby Creek. Above its confluence with Limestone Run, Little Toby Creek had a pH of 3.5, a conductivity of 1,150, and carried an acid load of 2,345 lb/day. One principal mine drainage source was located in this headwaters area.

Limestone Run

Limestone Run, the first tributary to the main stem, was seriously polluted by coal mine discharges. Fourteen discharges located within the 0.5 square mile drainage area of this tributary contributed a combined acid load of 6,900 lb/day. The principal portion of this acid load resulted from two discharges of the abandoned Limestone Run Mine. (Mine No.'s 920, 921) These discharges totalled 774 gpm and carried an acid load of 6,082 lb/day. At its mouth Limestone Run had a pH of 3.2, a conductivity of 1,600, and carried an acid load of 2656 lb/day. Mine No.'s 920 and 921 are identified as principal mine drainage sources.

Kyler Run

Kyler Run is the next downstream tributary to Little Toby Creek. This stream was also seriously polluted due to coal mine discharges. In terms of total source acid load, the mine discharges inventoried on this tributary watershed totalled the highest acid load of any tributary in the entire Toby Creek watershed. The upper portion of Kyler Run has been extensively mined by both surface and underground operations. These operations have left large piles of "gob", "red dog", and unreclaimed strip mine cuts. The large underground Kyler Mine was located near the headwaters area and many of the discharges resulted from this mine. Sixteen sources of mine drainage were inventoried at the Kyler Mine complex. The total acid load from these sources was 8,267 lb/day. Mine No. 946 had a measured discharge of 1,323 gpm and carried an acid load of 4,762 lb/day. With respect to volume and acid load, this discharge represented the largest single source of mine drainage pollution in the entire Toby Creek watershed. This large discharge comes from the base of a strip mine high wall where the later surface mine broke into the Kyler Mine workings. Mine No. 954, which discharged an acid load of 1571 lb/day to Kyler Run, was located on the hill approximately 100 feet above the Kyler Mine complex. This opening possibly served as a drainway for another mine reportedly located to the east that intersected the Kyler workings. Portions of the Kyler Valley have

been strip mined on at least three different elevations. One hilltop area strip was active at the time of the survey but had no discharge at the time of inspection. An acid load of 1,413 lb/day was discharged to Kyler Run by a strip pond effluent possibly fed by underground flow (Mine No. 939). At its mouth Kyler Run had a pH of 3.3, a conductivity of 1,350, and carried an acid load of 5,346 lb/day. Three principal mine drainage sources were located on Kyler Run, Mine No.'s 939, 946, and 954.

Little Toby Creek

Below Kyler Run the next sources of coal mine drainage that entered Little Toby Creek resulted from the abandoned Toby Mine. Mine No. 926 discharged an acid load of 1,576 lb/day to Little Toby Creek. The large acid load found at the time of the survey may be partly attributable to delayed surface runoff which flowed through the large gob pile located at this mine. Two mine seals were located at the Toby Mine complex. The acid load discharged by one seal was 156 lb/day. The other seal was dry. Near the southern corner of the Toby Mine complex a discharge of 440 gpm (Mine No. 1187) carried an acid load of 3,564 lb/day. This discharge drained from a partially slumped portal of what appeared to be a small mine. Due to the proximity of this mine to the nearby Toby Mine and the large discharge coming from the mine, it is possible that this portal may serve as a drainway for the Toby Mine at a point where the small drift mine intersected the Toby workings.

The area adjacent to Mine No. 1187 has had extensive contour strip mining on at least two different elevations. All but a small portion of this surface mine had been reclaimed. However, it was reported that abandoned deep mines had been stripped out. At the time of inspection numerous seepage points were present at the bottom edges of the disturbed areas. At Station No. 958 an automatic liming device had been constructed by a strip mine operator to treat a channeled discharge of 170 gpm which resulted from the cumulative seepage of the strip area. The pH of the treated discharge was raised from 3.2 to 5.5 and the acidity concentration lowered from 725 mg/l to 490 mg/l. However, after treatment the acid load carried by the discharge still amounted to 771 lb/day.

At Kyler's Corners, an unnamed tributary which drains a portion of the basin west of Kyler Run, enters Little Toby Creek. One drift mine, with an acid load of 2 lb/day, was the only discharge directly attributable to mining activity on this tributary. Directly across from this mine a 36 inch pipe located under the road discharged 635 gpm to this unnamed tributary. Due to the lack of any visible mining activity in this area it appears that this discharge may result from a

drainway to a mine located in a different portion of the basin, possibly the nearby Kyler Mine. The acid load carried by this discharge (Mine No. 984) was 3,543 lb/day.

Below Kyler's Corners and the downstream confluence of Brandy Camp Creek with Little Toby Creek, the main stem received only moderate amounts of mine drainage. McCauley Run had been contour strip mined along both sides of its entire length but no discharges were located. Restripping operations were active on this tributary during the survey. At its mouth McCauley Run had a pH of 6.8 and a conductivity of 850.

Due to the absence of point discharges, two tributaries on either side of McCauley Run were sampled near their mouths. The intermittent tributary upstream of McCauley Run received sub-surface seepage from strip mine operations and surface seepage from an abandoned and completely slumped drift opening. At its mouth (Station No. 986) this tributary had a pH of 6.7 and carried a net alkaline load of 25 lb/day.

Contour strip mine operations also contributed seepage to the tributary located downstream of McCauley Run. At its mouth (Station No. 987) this tributary had a pH value of 5.6 and carried a net acid load of 81 lb/day.

Downstream of McCauley Run, Sawmill Run had a pH of 4.3 and a conductivity of 600. Three abandoned drift mines and one combination underground-surface mine were located on this tributary. The total source acid load from these sources was 179 lb/day.

Below Sawmill Run four hilltop area strip mines were located on an unnamed tributary to Little Toby Creek. Two of these mines were active, however they were all dry.

Brandy Camp Creek

Karnes Run, Phalen Run, and Benninger Creek are the principal tributaries to Brandy Camp Creek in the headwaters area. There was no mining activity in the Phalen Run watershed. At its mouth, pH and conductivity values of 6.6 and 210, respectively, were recorded. Two strip mines and one deep mine discharge were located on Karnes Run. The combined acid load of these discharges totalled only 20 lb/day. The mouth of Karnes Run had a pH of 6.8 and a conductivity of 200. Three strip mine discharges with a combined acid load of 24 lb/day were the only sources of mine drainage located on Benninger Creek.

Mine No. 995 contributed the first significant amount of mine drainage to Brandy Camp Creek. At this location a stripped out deep

mine discharged an acid load of 110 lb/day to Brandy Camp Creek. Downstream of this mine the main stem received two large acid loads. Both of these discharges resulted from the Brandy Camp Mine complex. Mining maps show five portals to this mine, however, strip mines have either destroyed or covered these old entrances. Mine No. 998 discharged an acid load of 1,029 lb/day. The 220 gpm effluent emerged from what appeared to be an old covered portal. The 1,152 gpm discharge from Mine No. 996 arose near the base of strip spoil piles with a very noticeable artesian effect. The acid load carried by this mine effluent was 4,008 lb/day. The contour strip operations at the Brandy Camp Mine continued downstream along the main stem at two elevations for almost the entire length of the tributary. These operations destroyed openings to at least five deep mines that were located along this stretch of Brandy Camp Creek. Discharges from four of these mines contributed an additional acid load of 517 lb/day. Mine No. 1000 contributed the last significant acid discharge to Brandy Camp Creek. At this location a flow of 325 gpm, from the abandoned Blue Valley Mine, carried an acid load of 292 lb/day to Brandy Camp Creek. At its mouth Brandy Camp Creek had a pH of 3.7, a conductivity of 600, and discharged an acid load of 7,846 lb/day to Little Toby Creek. Mine No.'s 996 and 998 are identified as principal mine drainage sources.

Little Toby Creek

Below the community of Challenge and the downstream community of Brockport, mining activity was noticeably absent on the south side of Little Toby Creek. Bear Run and Boggy Run which enter the main stream in this stretch had pH values of 7.2 and 7.5. Each had a conductivity value of less than 50.

Johnson Run, Oyster Run, Mead Run

On the north bank, Johnson Run, Oyster Run, and Mead Run were the next downstream tributaries affected by mine drainage. Although these tributary watersheds have experienced considerable mining activity over nearly their entire drainage areas, only a limited number of discharges were found and the acid loads carried by the discharges were quite low.

Two deep mines and three strip mines discharged a total net acid load of only 3 lb/day to Johnson Run. One active deep mine was located on Johnson Run but it was not operating at the time of the source investigation. At its mouth Johnson Run had a pH of 6.6 and a conductivity of 750.

Only one source of mine drainage was found on Oyster Run. This was an abandoned deep mine discharge with a net alkalinity of 6 lb/day.

At its mouth Oyster Run had a pH of 7.1 and a conductivity of 400.

The headwaters of Mead Run have been extensively strip mined but no discharge points draining directly to the feeder tributaries which drain this area were located. Conductivity and pH values for this area were 4.6 and 825. The low pH was attributable to numerous seepage points along the bottom edges of the spoil piles located just above stream level. Four deep mine discharges and three strip mine discharges totalling 403 gpm were located along the main stem of Mead Run. At its mouth Mead Run had a pH of 6.9 and a conductivity of 450.

Little Toby Creek

Between the communities of Brockport and Brockway only small amounts of mine drainage entered Little Toby Creek. Below Brockport one drift mine discharging an acid load of 15 lb/day was located on the next downstream tributary to Little Toby Creek.

Walburn Run is the last tributary to Little Toby Creek before the confluence of the main stem with Rattlesnake Creek. Several drift mines and small strip cuts were investigated on the lower portion of Walburn Run but all were dry. One sizeable contour strip mine and several stripped out deep mines were located on the East Branch of Walburn Run, however, these were also dry. Near the headwaters of West Branch Walburn Run, two acid discharges were located. One of the discharges was from an old mine seal and the other was from the base of a gob pile located at this old mine. The combined acid load carried by these discharges was 209 lb/day. At its mouth Walburn Run had a pH of 6.6 and a conductivity of 280.

At its mouth (Station No. 1223), Little Toby Creek had a pH of 3.8, a conductivity of 625, and carried an acid load of 16,888 lb/day. The confluence of Little Toby Creek and Rattlesnake Run forms Toby Creek.

Rattlesnake Run

Rattlesnake Run drains the portion of the Toby Creek watershed south and southwest of the town of Brockway. The principal tributaries are McEwen Run and Rattlesnake Creek.

The Rattlesnake Run watershed is one of the most extensively mined areas in the entire Toby Creek watershed. The area was at one time extensively deep mined and later strip mined. At the time of the mine drainage survey, several surface mine operations and three drift mines were active. In spite of the numerous mining operations on

the east side of Route 219, only ten discharging sources were located. Three of these discharges were from the active drift mines. The total measured discharge from all sources was 690 gpm, which carried a net acid load of only 26 lb/day. The largest discharge (Mine No. 1248) found on Rattlesnake Run was a 300 gpm flow from an abandoned underground mine near the community of Westville. This mine discharge had a pH of 6.9 and a net alkalinity concentration of 53 mg/l. Several homes in the immediate area had tapped this mine effluent for water supply. A large contour strip mine was located on main stem Rattlesnake Run below the confluence of Rattlesnake Creek on the east side of Route 219. An active strip and auger mine was located at the north end of this contour strip mine, however, no discharge points were located. At its mouth Rattlesnake Run had a pH of 7.5 and a conductivity of 650.

McEwen Run, Rattlesnake Creek

Both surface and underground mines were located on McEwen Run, however, acid discharges from these coal mine sources were negligible. The surface mine on the north bank of McEwen Run extends around the face of the hill and into the Rattlesnake Creek drainage area. One deep mine was destroyed by this surface mine, however, it discharged to Rattlesnake Run. A clay mine was in operation on McEwen Run during the survey but it was dry. At its mouth McEwen Run had a pH of 6.5 and a conductivity of 120.

Cumulative seepage from an abandoned coal yard or loading area contributed an acid load of 9 lb/day to Rattlesnake Creek. Considerable coal and shale refuse was scattered about this area. Any deep mine openings which may have been located at this point have been destroyed by the surface mine extending along the south bank of Rattlesnake Creek.

Toby Creek

Below the town of Brockway, Baghdad Run was the last tributary to Toby Creek on which mine discharges were located. Three abandoned drift mines and one combination drift mine discharged a total acid load of 17 lb/day to Baghdad Run. At its mouth Baghdad Run had a pH of 6.9 and a conductivity of 170. Between Baghdad Run and the next downstream tributary, Jenkins Run, one large contour strip mine was investigated, however, it was dry. This strip mine was the last mining activity between this point and the confluence of Toby Creek with the Clarion River.

Acid stream conditions persisted in Toby Creek from the area of mine discharges, downstream the remaining 11 miles, to the mouth.

At its mouth Toby Creek had a pH of 3.9, an acidity concentration of 125 mg/l, and discharged an acid load of 14,936 lb/day to the Clarion River.

DISCUSSION

Toby Creek and many of its tributaries are grossly polluted by coal mine drainage. These streams are acidic, highly mineralized, and devoid of normal aquatic life. The entire length of Little Toby Creek and Toby Creek was so affected.

The drainage areas of Brandy Camp Creek and Little Toby Creek above Kylers Corners, represent the two areas in the Toby Creek watershed which were the most seriously degraded by mine drainage. All of the twelve principal mine drainage sources are located within these two headwater drainage areas. Table 3 presents an area breakdown of mine drainage in terms of the total flow and total loading (lb/day) of polluting constituents discharged to receiving streams in the Toby Creek watershed.

Acidity

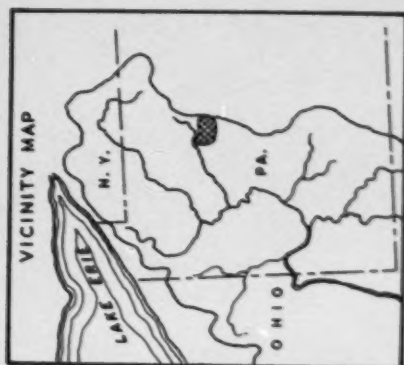
From Table 3, a total acid load approaching 19 tons per day was discharged by 122 sources at the time of the study. Approximately 80 percent of this total load (29,831 lb/day) was discharged to Toby Creek and its tributaries from only 12 mine discharge points. An additional 110 sources scattered throughout the watershed contributed an acid load of some 3.8 tons per day.

An average acid load of 7.5 tons per day was measured at the mouth of Toby Creek (Station No. 0518). This load is some 11 tons per day less than the total source acid load measured. The decrease is primarily attributable to the neutralizing capacity of alkaline water draining to the main stream, particularly in its lower reaches. Varying hydrologic conditions during the summer of 1966 affected the acid load carried at the mouth of Toby Creek. However, the maximum acid load measured at the mouth of Toby Creek approximated only 50 percent of the total source acid load. The acid load varied from a minimum of 7,225 lb/day to a maximum of 19,233 lb/day.

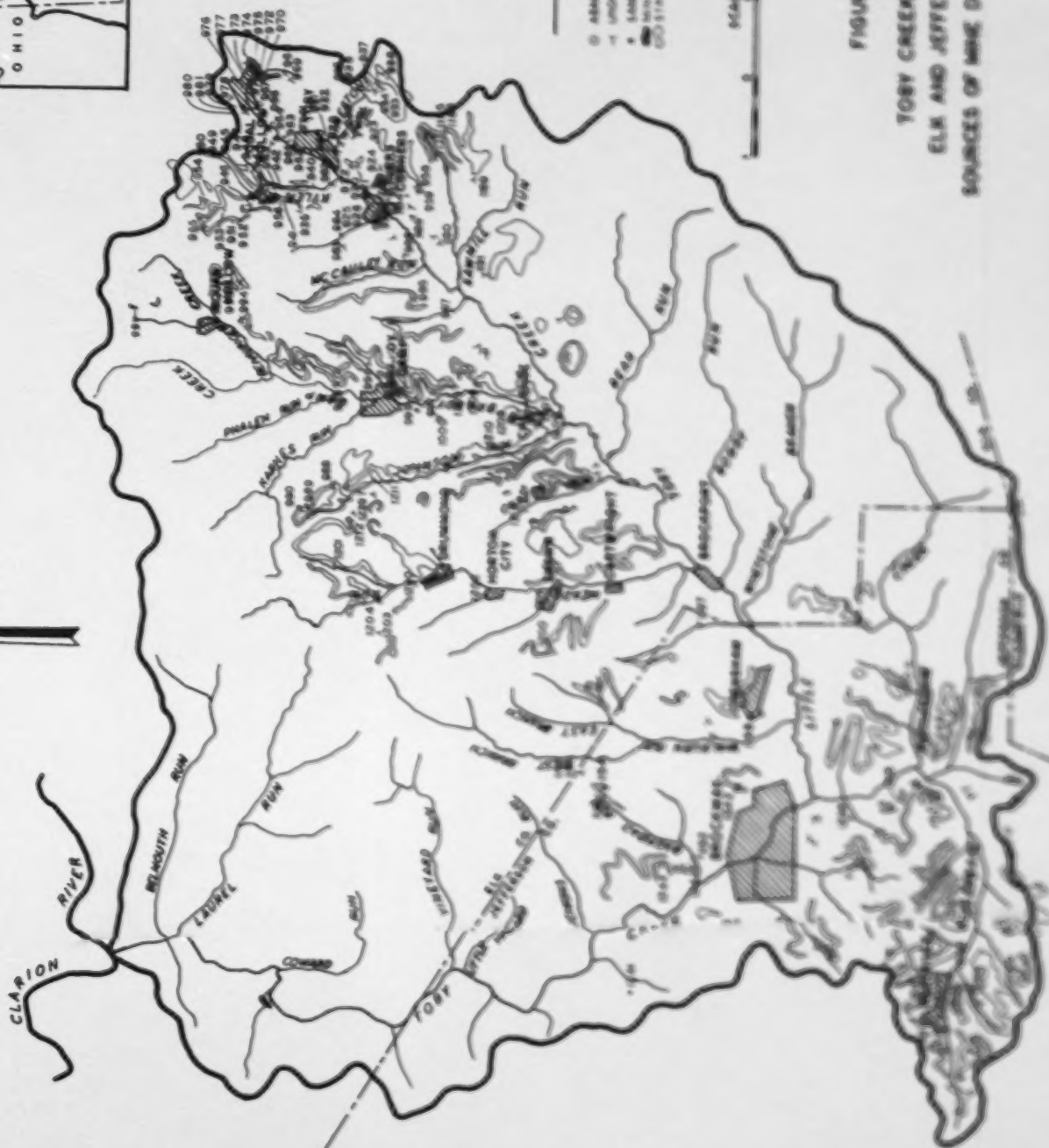
The highest total acidity concentration encountered during the survey was 2,370 mg/l from drainage emerging at the base of strip mine spoil piles.

Alkalinity

Alkalinity was present in 34 of the 122 discharges sampled. Only



28a



—LEGEND—

- ABANDONED GAS WELL
- UNDERGROUND MINE
- SAMPLING POINT LOCATION
- ▨ MINE KILN
- OLD STOP MINE

SCALE IN MILES

FIGURE 3

TOBY CREEK WATERSHED
ELK AND JEFFERSON COUNTIES
SOURCES OF MINE DRAINAGE POLLUTION

Table 3

Mine drainage loadings by receiving stream
Toby Creek watershed, Elk and Jefferson Counties

Receiving Stream	Stream Mile 1/	Drainage Area (sq. mi.)	No. of Mine Discharges	Total Discharges (gpm)	Net Acidity (lb/day)	Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Toby Creek	-	-	29	2,313	8,053	9,130	19,356	228	369
Tribes to Toby Cr.	-	-	13	1,275	7,764	7,897	18,024	706	455
Limestone Run	25.0	0.5	14	946	6,897	2,813	10,064	422	163
Brandy Camp Cr.	20.5	11.2	9	1,904	5,952	6,772	14,778	579	175
Karnes Run 2/	-	-	3	11	20	72	96	0	2
Benminger Cr. 2/	-	-	3	21	24	35	55	0	2
Kyler Run	24.9	2.6	16	2,393	8,267	7,294	17,262	317	306
Walburn Run	14.0	6.5	2	85	209	251	495	3	1
Mead Run	17.1	6.5	7	403	-7	1,362	1,375	22	22
Sawmill Run	22.6	1.5	4	24	179	170	392	8	14
Baghdad Run	10.7	1.4	4	27	17	44	55	0	0
Johnson Run	20.2	3.9	5	8	3	22	31	1	1
Rattlesnake Run	12.8	19.1	10	690	26	3,159	3,338	25	4
McEwen Run 3/	-	-	1	1	1	2	3	0	0
Rattlesnake Cr. 3/	-	-	1	3	9	9	21	0	1
Oyster Run	18.5	1.3	122	60	-6	220	187	0	0
				10,164	37,408	39,252	85,532	2,311	1,515

1/ Distance above mouth of Toby Creek. 2/ Tributary to Brandy Camp Creek. 3/ Tributary to Rattlesnake Run.

14 of these discharges had alkalinity concentrations in excess of acidity concentrations. No alkalinity was present at any of the stream sampling stations.

Hardness

A total of 19.7 tons per day of hardness was discharged to the streams of the watershed by the sources measured. This load closely approximates the 20 ton per day average load which was measured at the mouth of Toby Creek.

The highest total hardness concentration encountered in the watershed was 2,310 mg/l from Mine No. 1201, an abandoned strip mine.

Ions in coal mine drainage contributing to hardness in significant amounts are calcium, magnesium, manganese, iron and aluminum.

Sulfate

Acidic and alkaline mine waters both commonly contain high concentrations of sulfate ion. The source of sulfate in these effluents are free sulfuric acid and dissolved sulfate salts. The sulfate content of receiving streams in coal mining areas is indicative of the amount of total acidity that has been discharged to them by mine drainage. This sulfate content is the residual component of neutralized acidity as well as a component of acidity not yet subjected to neutralization.

The twelve principal mine discharges in the basin discharged 63 percent of the total measured sulfate load. The highest sulfate load encountered in the watershed was nearly 5 tons per day from Mine No. 946, a stripped out underground mine.

Total Iron

Iron concentrations and loads were excessive at each stream sampling stations shown in Table 2. A total of 1.15 tons per day of iron was discharged to Toby Creek by coal mine sources. At its mouth Toby Creek carried an average iron load of only 140 lb/day. Much of the iron load discharged by coal mine sources is precipitated and deposited on stream bottoms or is in intermittent stream transit between the drainage sources and the mouth of Toby Creek.

The largest source of iron found, 533 lb/day, was discharged by Mine No. 984.

Manganese

Similar to the occurrence of iron, manganese concentrations were

high at all stream locations in Table 2. The highest manganese concentration was found at the mouth of Limestone Run, 22 mg/l. The manganese load at the mouth of Little Toby Creek was 928 lb/day which increased to 1,009 lb/day at the mouth of Toby Creek. A total manganese load of 1,515 lb/day was discharged to the watershed streams from coal mine sources.

Table 4 presents a summary of flow volumes and chemical loadings, by type of source, for the 122 discharging sources inventoried.

At the time of the study there were only three active mining operations with measurable discharges in the watershed. These operations, all drift mines, contributed a net acid load of only 103 lb/day, less than 0.3 percent of the total source acid load.

Abandoned strip mines were responsible for 16 percent of the total mine drainage discharge in the watershed and contributed 1,198 lb/day of the total source acid load, about 3 percent.

Abandoned underground mines, including combination underground mines were the principal mine drainage pollution source type. These 90 sources discharged the following percentages of each parameter: flow (gpm) - 90 percent, net acidity - 96 percent, hardness - 92 percent, sulfate - 93 percent, total iron - 99 percent, manganese - 96 percent.

POLLUTION ABATEMENT

From the preceding discussion it is apparent that particular pollution abatement emphasis will have to be placed upon abandoned underground and combination underground-surface mines. Since 96 percent of the total watershed acidity emanated from these sources, abatement within these two source categories should effect significant water quality improvement in the Toby Creek watershed. However, physical abatement of all 90 sources is economically undesirable. Abatement of all 90 sources would include many mines which contributed only an insignificant amount of mine drainage pollution. A more reasonable approach to drainage abatement involves the selection of major discharges within the watershed. Twelve major sources (principal sources) of mine acidity in the watershed have been selected. These individual mine sites are selected with respect to the magnitude of their acid loads and the relative contribution of each source to the total watershed problem. While this preliminary selection represents a substantial reduction in the number of sources selected for abatement, it remains possible through effective abatement techniques to insure significant water quality improvement in the receiving streams of the

Table 4
Mine drainage loadings by source type
Toby Creek watershed, Elk and Jefferson Counties

Source Type	No.	Total Discharges (gpm)	Total Net Acidity (lb/day)	Total Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Drift Mine (inactive)	62	5,315	21,820	20,421	46,589	1,435	760
Drift Mine (active)	3	200	103	898	1,059	17	1
Strip Mine (inactive)	28	861	1,198	2,349	3,986	17	59
Combination ^{1/} Drift Mine (inactive)	28	3,786	14,287	15,584	33,898	842	695
Crop Seep	1	2	0	0	0	0	0
Totals	122	10,164	37,408	39,252	85,532	2,311	1,515

^{1/} Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the underground mine.

watershed. The total acid load discharged by the 12 principal sources was 29,831 lb/day.

In order to predict the stream effect resulting from mine drainage pollution control, it is necessary to consider a critical chemical parameter on which calculations may be based. Since Toby Creek is a consistently acid stream with no industrial acid sources in the basin, and since acidity is usually considered the single most devastating property of coal mine drainage, total stream acidity is used in this discussion to predict water quality improvement. Similar reductions in other mine drainage parameters (hardness, sulfate, iron, manganese) are expected to be coincident with acidity reduction.

Through the use of their bond issue money the Commonwealth of Pennsylvania has initiated additional engineering studies in the Toby Creek watershed since completion of the 1967 survey. This study is involved with the development of an abatement plan for one of the abandoned mine complexes in the watershed.

PRINCIPAL SOURCES

Twelve mine drainage sources are identified as principal watershed pollution sources (Table 5.) All of these sources are underground mines or combination underground-surface mines. There are no active mining operations classified as principal sources.

In the Toby Creek watershed all mine sites which contributed an acid load in excess of 1,000 lb/day are considered as principal sources.

The combined acid load of the 12 principal sources was 29,831 lb/day. (Table 5).

In view of the present technical unknowns involved in the abatement of mine drainage, present methods cannot always be expected to reach a maximum degree of effectiveness. For both the underground mining sites and the combination underground-surface mines, a 75 percent reduction in acid loads may represent the maximum degree of effectiveness achievable through current abatement techniques.

Assuming the 75 percent reduction limit, over 11 tons per day (22,373 lb/day) of acidity would be removed from the receiving streams of the watershed.

Such acidity reduction at the discharge points would effect a similar reduction at the mouth of Toby Creek. The acidity reduction which is assumed through principal source abatement exceeds the average acid load measured at the mouth of Toby Creek during the 1966 stream survey (Table 2). It is unrealistic to assume that abatement of these twelve sources would totally eliminate the acid condition found at

Table 5

Principal acid mine drainage sources
Toby Creek watershed, Elk and Jefferson Counties

Station Number	Type of Mine	Flow (gpm)	pH	Specific Conductance ^{2/}	Acidity (mg/l-lb/day)	Receiving Stream
920	Drift Mine	387	2.9	1,650	765 3,552	Limestone Run
921	Drift Mine	387	2.9	1,500	545 2,530	Limestone Run
926	Drift Mine	180	3.0	1,500	730 1,576	Trib. to Toby Creek
939	Drift Mine ^{1/} Combination	380	3.9	1,400	310 1,413	Kyler Run
946	Drift Mine Combin- ation	1,323	3.2	1,300	300 4,762	Kyler Run
954	Drift Mine	90	2.6	3,000	1,455 1,571	Kyler Run
958	Drift Mine Combination	170	5.5	2,200	490 771	Trib. to Toby Creek
960	Drift Mine	400	3.5	1,200	315 1,512	Toby Creek
984	Drift Mine	635	4.6	1,600	465 3,543	Trib. to Toby Creek
996	Drift Mine Combination	1,152	2.8	1,200	290 4,008	Trib. to Brandy Camp
998	Drift Mine	220	3.1	1,400	390 1,029	Brandy Camp Creek
1187	Drift Mine	440	2.8	2,500	675 3,564	Toby Creek
					Total - 29,831 lb/day	

^{1/} Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the underground mine.

^{2/} Specific conductance measured as micromhos/cm.

the mouth of Toby Creek. However, the acid reduction achieved through physical abatement of these twelve sources should significantly reduce the acid load found at the mouth of Toby Creek. The mine source data was collected during a relatively short time period and is not representative of the varying hydrologic periods. Such a limitation prohibits accurate quantitative predictions during the course of an entire water year. Before such long-term water quality improvement predictions can be justified, a program of repetitive water quality monitoring to accurately correlate stream flow conditions with mine discharge characteristics would be required.

The principal source abatement approach outlined in this document (12 sources) should prove sufficient to significantly improve the water quality in the Toby Creek watershed. However, as previously stated there is insufficient water quality data available to accurately predict the cumulative effect of source abatement. A recommendation relative to the development of the necessary data is given on page 3. If future data development and economic or technical constraints prove the infeasibility of the principal source abatement approach, as outlined, it may be necessary to add or delete sources due to the development of more valid correlations between stream water quality and mine discharge characteristics. Until such a time the principal source approach can effectively serve as a first phase or priority in a program of drainage source abatement.

The following is a more detailed description of the 12 principal sources recommended in this document for mine drainage abatement. The locations of the principal source sites are shown in Figure 4.

Mine No.'s 920 and 921:

These mines are located on Limestone Run. The discharges drain from openings in the hillside near the head of a ravine and were located within ten feet of each other. The area around the discharge points was slumped and the drainage emerged at the surface with a noticeable artesian effect. The openings were probably drainways or similar accesses to the old Limestone Run Mine located directly over the hill to the northeast. Sources 920 and 921 were obviously interconnected. The hillside containing the openings has been contour strip mined and area residents reported that this drainage did not exist prior to the surface mine operation. The combined flow of these sources was 774 gpm and they carried an acid load of 6,082 lb/day to Limestone Run.

Mine No. 926:

An acid load of 1576 lb/day was discharged to an unnamed tributary

of Toby Creek from this site. The acid load carried by this discharge resulted from delayed surface runoff which flows through and around extensive mine waste dumps from the old Toby Mine complex at this location. The 180 gpm effluent was at high flow when sampled due to heavy recent rains.

Mine No. 939:

Mine No. 939 was located in the Kyler Valley Mining complex. The origin of this source was a small strip mine pond located on the west bank of Kyler Run near the southern extremity of the mining activity. The pond was quite small, no more than 25 yards in length, and the bottom was visible over the entire area. However, the discharge of 380 gpm suggests the pond was fed by an underground source. The acid load carried by this discharge was 1413 lb/day. There were three principal mine drainage sources located on Kyler Run, Mine Nos. 939, 946, and 954.

Mine No. 946:

Mine No. 946 had a measured discharge of 1,323 gpm and carried an acid load of 4762 lb/day. With respect to the volume and the acid load carried by the discharge, this was the largest single source of mine drainage pollution in the Toby Creek watershed. This discharge emerged from the base of a strip mine highwall with a very noticeable artesian effect. The point of discharge marks the location where a surface mine broke through into the underground Kyler Mine workings.

Mine No. 954:

The discharge from this mine was located near the headwaters of Kyler Run. It was approximately 100 feet above the mining activity in the Kyler Valley. There was nothing in the immediate area which suggested mining operations at this exact location, however, this discharge point may serve as a drainway for another mine reportedly located to the east which intersected the Kyler Mine workings. The acid load carried by this discharge was 1571 lb/day.

Mine No. 958:

This sampling point represented a mine discharge before and after treatment by an automatic liming device. The effluent represented seepage accumulation from the bottom edge of a large reclaimed strip mine area. During the survey it was reported that deep mines had once been operative in this small valley but all traces have since been destroyed by surface mining. The numerous seepages have been channeled to an automatic liming device. At the time of sampling, the treatment process raised the pH of the drainage from 3.2 to 5.5 and lowered the acidity

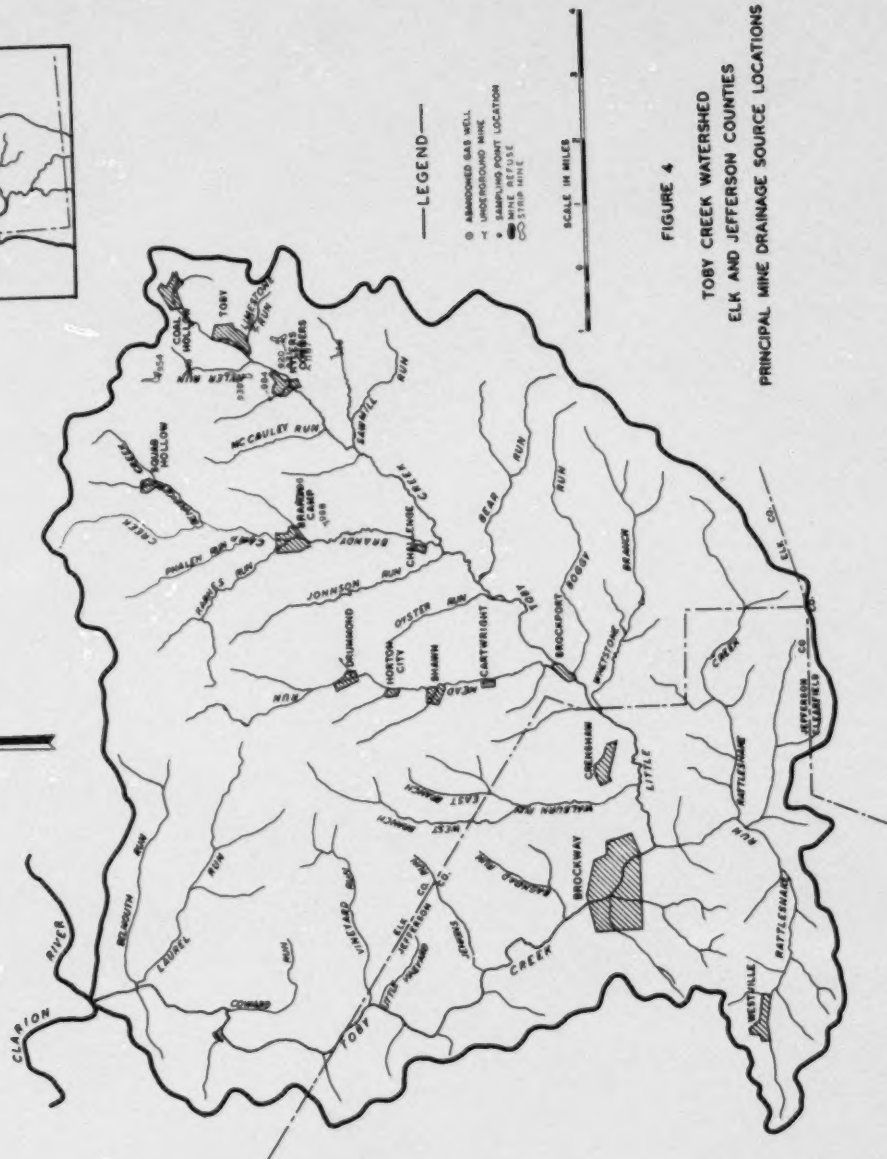
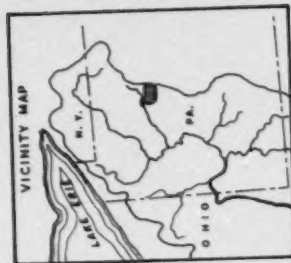


FIGURE 4
TOBY CREEK WATERSHED
ELK AND JEFFERSON COUNTIES
PRINCIPAL MINE DRAINAGE SOURCE LOCATIONS

concentration from 725 mg/l to 490 mg/l. However, the post-treatment acid load of the drainage still amounted to 771 lb/day with a flow of 170 gpm. Although this load is below the arbitrarily set limit of 1,000 lb/day, in order to qualify as a principal drainage source, its inclusion is due to the fact that only by perpetual lime treatment was the load reduced to this 771 lb/day load. The pre-treatment load was 1,566 lb/day.

Mine No. 960:

Just north of the community of Toby, a number of structures were located that appear to be Works Progress Administration mine seals from the program of the 1930's. Most of the seals appeared intact with only minor signs of exterior deterioration. The sealed opening on the down-slope side of this series of mine seals, Mine No. 960, had a discharge of 400 gpm and carried an acid load of 1512 lb/day. The discharge was piped under a road bed and then flowed a short distance to Little Toby Creek. This opening is believed to be part of the old Toby Valley Coal Company mine. This discharge was the largest acid contributor to Little Toby Creek upstream of its confluence with Limestone Run.

Mine No. 984:

At Kyler's Corners an unnamed tributary which drains a portion of the basin west of Kyler Run enters Little Toby Creek. One drift mine, with an acid load of 2 lb/day, was the only discharge directly attributable to mining activity in this tributary watershed. Directly across from this mine a 36 inch diameter pipe located under the road discharged 635 gpm to this unnamed tributary. Due to the lack of any visible mining in this area it appeared that the discharge drained a mine located in a different part of the basin. The acid load carried by this discharge (Mine No. 984) was 3,543 lb/day.

Mine No. 996:

Mining maps show the existence of at least five portals to the Brandy Camp Mining complex. Contour strip mining has destroyed or covered these old openings. The 1,152 gpm discharge from Mine No. 996 originated at the base of the strip spoils and apparently marks the location where the strip operation cut into the old Brandy Camp workings. The discharge was noticeably artesian and carried an acid load of 4,008 lb/day.

Mine No. 998:

The second principle discharge of the Brandy Camp mining complex

was located below Mine No. 996, near the mouth of the unnamed tributary that drains this area. Contour strip operations were located both above and below this old opening which was completely slumped. The 220 gpm measured discharge of this mine effluent carried an acid load of 1,029 lb/day.

Mine No. 1187:

Mine No. 1187 was located just east of Kyler's Corners on the east bank of Toby Creek. The small gob pile at this site suggests that only limited mining occurred at this site. Due to the proximity of this mine to the nearby Toby Mine and the 440 gpm discharge coming from the mine, it appears that this portal may serve as a drainway for the Toby Mine at a point where the small drift mine intersected the Toby workings. The acid load discharged by this mine was 3,564 lb/day.

SUMMARY AND CONCLUSIONS

1. The Deer Creek watershed, draining 69 square miles of Clarion County, Pennsylvania, has been severely degraded as a result of coal mine discharges. Both underground and surface mining methods are common in the watershed, however, these operations are of only limited size. The Deer Creek watershed has the additional pollution problem of abandoned gas wells whose effluents exhibit chemical characteristics similar to those of acid mine drainage.
2. The degraded water quality of Deer Creek extends the entire length of the main stream as well as affecting many miles of tributary streams. The streams draining the coal and gas fields were acidic, highly mineralized, and devoid of normal aquatic life.
3. Approximately 100 mining sites and an estimated 1,600 acres of strip mined area were investigated during this study. Samples for chemical analysis were collected from 59 sources discharging at the time of the survey. Discharges from coal mine sources ranged from one to 36 gallons per minute (gpm) and from one to 496 gpm from abandoned gas well sources. The total effluent volume from all sources was 1,403 gpm or approximately 2 million gallons per day. The pH of the effluents ranged from 2.3 to 7.4 and total acidity concentrations as high as 9,235 mg/l were recorded. Only four of the 59 discharging sources were alkaline. The total acid load (less alkalinity) discharged to Deer Creek and its tributaries equalled 10,711 lb/day.
4. The only active source of acid pollution at the time of the survey was a coal preparation plant. Inactive or abandoned drift mines and abandoned gas wells were the principal sources of acid pollution. These sources were responsible for 72 percent of the total mine acidity measured in the watershed.
5. Thirteen mine drainage sources are identified as principal watershed pollution sources. These sources consist of two drift mines, one strip mine, three combination underground-surface mines, one coal preparation plant, and six gas well effluents. The combined acid load of these 13 sources was 8,748 lb/day, about 81 percent of the total measured acidity.

DESCRIPTION OF AREA

Deer Creek rises in north central Clarion County, Pennsylvania and flows generally south some 18 miles to its confluence with the

Clarion River at mile point 21.3. The watershed drains 69 square miles located entirely in Clarion County. The watershed, somewhat long and narrow, is about 18 miles in length and about eight miles at its maximum width (east-west).

In the downstream areas of the watershed the valleys are V-shaped and the hillsides are steep and abrupt. The topography moderates considerably in the upper reaches of the watershed as the valleys widen and hillside slopes decrease.

Paint Creek is the principal tributary to Deer Creek and drains 40 square miles of the total 69 square mile watershed drainage area. Shippenville is the principal population center within the watershed with a 1960 population of 600. None of the remaining communities had 1960 populations exceeding 300.

The Deer Creek drainage area is bounded on the east by Toby Creek, on the south and west by the Clarion River and its minor tributaries and by drainage to Tionesta Creek on the north.

Mining in the Deer Creek watershed has been almost exclusively limited to hilltop or flat land operations. The majority of the surface mine operations were area strip mines many of which were associated with small drift mines. The mine operations were generally restricted to the moderate topography of the headwater areas. There were no coal mining operations located in the valley bottoms in the downstream portions of the watershed.

Since the underground mines located during the survey were all drift operations they are naturally of limited size due to their location. There were no major underground mines located in the watershed. With the exception of an approximately 15 square mile area north of Shippenville, mining operations were evenly distributed about the perimeter of the watershed.

STREAM WATER QUALITY

Deer Creek, principal tributaries to Deer Creek, and numerous unnamed tributaries within the watershed were polluted by coal mine drainage. This degraded water quality was evident from the uppermost reaches of the watershed and persisted over the entire downstream length. The affected streams of the watershed were acidic, highly mineralized and devoid of normal aquatic life.

The Deer Creek watershed experiences the additional problem of abandoned gas well effluents. These discharges are chemically

similar to coal mine discharges.

During the course of the field study several stream locations (Table 6) were sampled for chemical analysis. These stations were selected to measure the cumulative effects of mine drainage. Additionally, stream sampling data collected near the mouth of Deer Creek during the 1966 stream sampling program is included. A summary of all stream data is presented in Table 7.

In conjunction with sampling and flow measurements at selected stream locations, pH and specific conductance determinations were made at a number of additional stream locations in the watershed. These values and the location of stream sampling stations are shown in Figure 5.

Station No. 4596

This station was located on Paint Creek just above the confluence with Step Run. At this point Paint Creek carried a daily acid load of some 4 tons per day (Table 7). Other mine drainage parameters including iron and sulfate were excessive. At this point the stream was highly discolored, primarily due to two large gas-well effluents at its headwaters.

Station No. 4594

The water quality along the entire length of this small tributary was affected by acidic discharges from mines and gas wells. An acid load of 759 lb/day was measured at the mouth of the tributary. A total source acid load exceeding one ton per day was discharged from the individual sources.

A particular problem area existed on this tributary concerning the unknown effects upon stream water quality due to a swamp area which appeared highly influenced by abandoned gas-well effluents. This swamp area was located near the middle of the tributary. At this point the water of the tributary was diverted around and through the swamp area. The limited investigation of this area showed the presence of much iron discolored water "veiling up" from the surrounding area. No point discharges were located emanating from gas wells, however, there was evidence of old gas well drilling in the area.

Station No. 4587

A residual acid load of 4.5 tons per day was measured at the mouth of Paint Creek. This represents approximately 0.7 ton per day of acidity in excess of what was measured at the individual mine sites.

Table 6

Stream water quality sampling stations, Deer Creek watershed, Pennsylvania

Station No.	Sampling Period	Stream	Location
4596	Oct. 1967	Paint Creek	Above Step Run
4594	Oct. 1967	Little Paint Creek	Near Mouth
4587	Oct. 1967	Paint Creek	Near Mouth
4586	Oct. 1967	Deer Creek	Above Paint Creek
4588	Oct. 1967	Deer Creek	Near Mouth
0514	June, Aug., Sept. 1966	Deer Creek	Near Mouth

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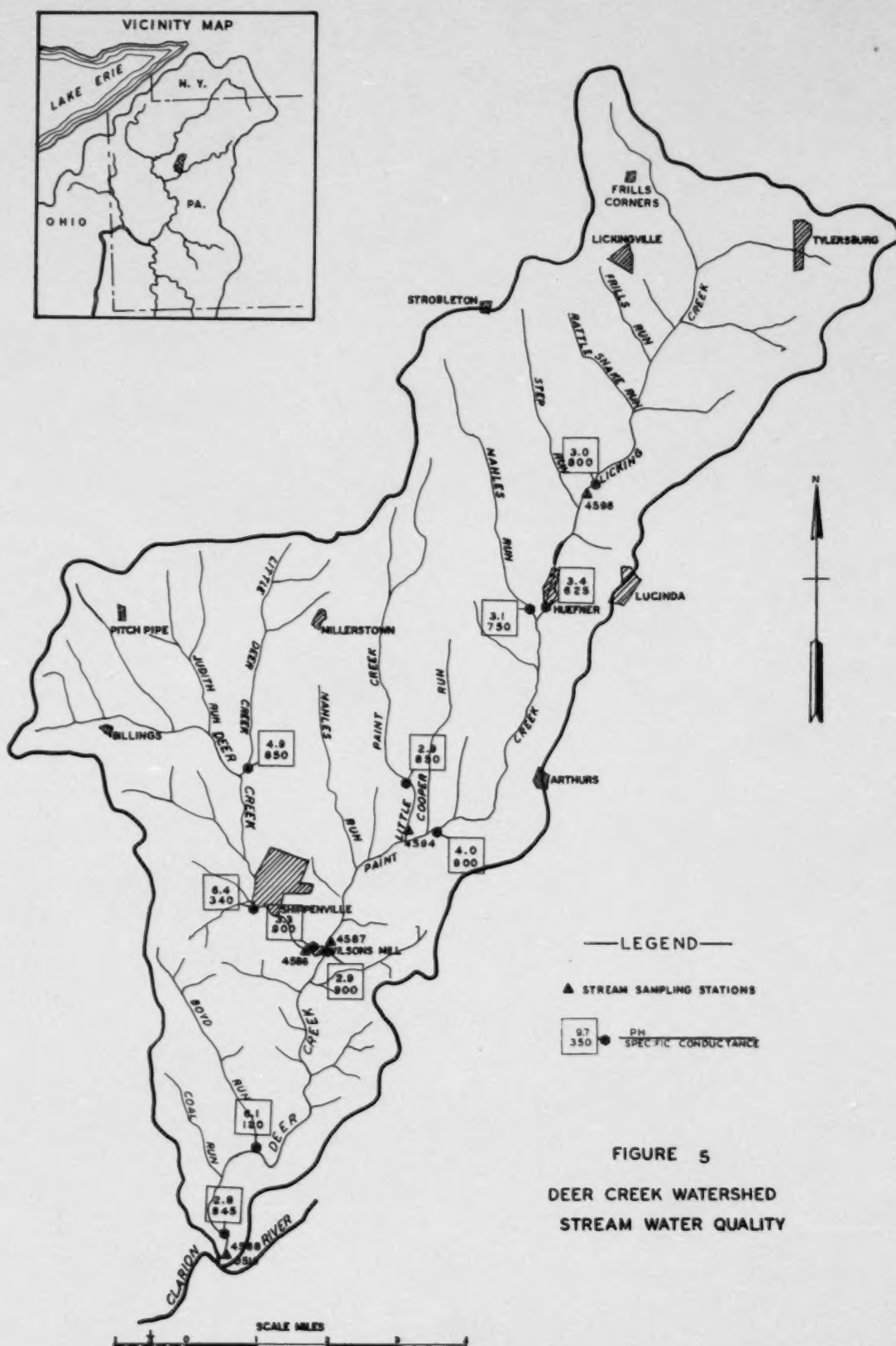


Table 7

Streamwater quality, Deer Creek watershed

Station Number	No. of Samples	Flow (gpm)	Specific Conductance	Total Acidity mg/l	Total Hardness mg/l	Sulfate mg/l	Total Iron mg/l	Manganese mg/l
4596	1	4,122	800	7,914	129	270	5.0	6.4
4594	1	333	1,000	759	135	405	5.0	10.8
4587	1	4,671	900	8,968	141	310	5.0	7.4
4586	1	792	900	2,518	142	350	3.0	9.0
4588	1	7,110	845	21,756	89	280	3.0	7.0
0514 ^{1/2}	6	8,685	867	13,845	189	281	4.8	8.9

1/ Additional sampling of Station No. 4588, conducted prior to the mine drainage source investigation

2/ Average of 6 samplings, 1966

3/ Specific conductance measured as micromhos/cm.

This difference is attributable to the varying hydrologic periods and increments of mine acidity throughout the sub-watershed which are not directly quantifiable. The sulfate and iron loads at this point were 9 tons per day and 280 lb/day, respectively.

Station No. 4586

This station was located on Deer Creek just above the confluence with Paint Creek. The stream carried a daily acid load of 1.25 tons. Sulfate, hardness, and iron loads were also high but not as excessive as those carried by other streams in the watershed.

Station No.'s 4588, 0514

At its mouth Deer Creek carried excessive amounts of all mine drainage related parameters. During the 1966 stream survey, Deer Creek discharged an average acid load of 6.9 tons per day to the Clarion River (Table 7). The minimum load value found during the 1966 survey was 5 tons per day while the maximum value was nearly 9 tons per day. The total acid load from the individual discharging mine sites was 5.1 tons per day.

BIOLOGY

A biological evaluation of Deer Creek at Station No.'s 4588 and 0514, Deer Creek near mouth, was conducted during 1966 to determine the effect of pollution conditions upon normal aquatic fauna. The benthic organisms collected consisted almost entirely of acid-tolerant forms. The substrate of the stream was characterized by physical evidence of mine drainage pollution which included red stains on rocks, sediment characteristics, and lack of biological growths.

In summary, all mine drainage affected stream locations sampled were characterized by pH values below 3.3 and specific conductance values above 800 micromhos/cm. Alkalinity concentrations were depleted to zero and acidity concentrations ranged from 160 mg/l to 265 mg/l.

Most of the watershed streams draining coal mine or gas well areas were characterized by red appearance and the presence of an orange-yellow precipitate in suspension or on the stream bottom. During periods of high stream runoff, the streams become extremely turbid due to flushout and resuspension of stream bottom deposits that resulted from drainage of mined areas.

SOURCES OF MINE DRAINAGE

Approximately 100 mining sites and an estimated 1,600 acres of strip mined area were investigated during this study. Samples for chemical analysis were collected from 59 sources discharging at the time of the survey. Discharges from coal mine sources ranged from one to 36 gpm and from one to 495 gpm from gas well sources. The total effluent volume from all sources was 1,403 gpm or about 2 mgd. The pH values of the effluents ranged from 2.3 to 7.4 and total acidity concentrations as high as 9,235 mg/l were recorded. Only four of the 59 discharging sources were alkaline. The total acid load (less alkalinity) discharged to Deer Creek and its tributaries was 10,711 lb/day.

A detailed description of the mine drainage sources in the Deer Creek watershed follows. All mine location sites inventoried in the watershed are shown in Figure 6.

PAINT CREEK

Headwaters

The headwaters of Paint Creek arise near the communities of Tylersburg and Frills Corners and flow south along State Route 68 past the communities of Lucinda and Arthurs to the confluence with Deer Creek at Wilsons Mill.

An area strip mine located north of Frills Corners discharged the first significant amount of mine drainage to an unnamed tributary of Paint Creek. The strip mine operation had been backfilled and graded to contour, however, two seepage areas were located along the edge of the mined area. The flow at these two points totalled 10 gpm and carried a combined acid load of 485 lb/day (Mine No.'s 4520, 4521). Mine No. 4520 is a principal watershed pollution source and is identified in a later section.

North of Lickingville a second area strip mine discharged an acid load of 69 lb/day to the same, above mentioned unnamed tributary. In addition, there were seepage areas occurring at the northeast and southwest parts of the disturbed area.

At Tylersburg, an abandoned gas well effluent contributed a discharge of 212 gpm to a headwater tributary of Paint Creek (No. 4532). The acid load carried by this effluent was 712 lb/day, and it is identified as a principal watershed pollution source. An area strip mine is located on the hill above this gas well, however, it was dry. Two underground mines are associated with this strip operation;

one was dry while the second contributed a one gpm flow from a mine seal (Mine No. 4525). A second mine seal was located at the base of an area strip mine directly west (across road) of Mine No. 4525. An acid load of 104 lb/day was measured at this mine (Mine No. 4527).

East of Tylersburg on State Route 36 a second large gas well effluent discharged to the same unnamed headwater tributary mentioned above. At the well site a flow of 495 gpm was coming to the surface with a noticeable artesian effect. The acid load carried by the discharge (No. 4531) was 1,722 lb/day and was the second largest load encountered in the watershed.

In addition to the acid loads discharged by gas well No.'s 4532 and 4531, these principal sources were primarily responsible for the high discoloration of the receiving stream. Much of the total 219 lb/day iron load was precipitated on the stream bottom or carried in suspension which imparted extreme discoloration for much of the downstream length of Paint Creek.

Frills Run

Frills Run is the first named tributary to Paint Creek which was degraded by either coal mine or gas well discharges. An area strip mine was located at the headwaters of this tributary but no discharges were inventoried at the time of the field study. However, as evidenced by a path of dead trees 100 yards wide, severe leaching occurs along the perimeter of the strip mine during periods of wet weather.

South of Lickingville a well well effluent was located adjacent to the east bank of Frills Run. This 120 gpm discharge carried an acid load of 619 lb/day and was responsible for the degraded water quality and high discoloration of Frills Run over its entire length at the time of study. This gas well effluent (No. 4516) is identified as a principal watershed pollution source.

Rattlesnake Run

Rattlesnake Run and a small unnamed tributary which joins Paint Creek on the bank opposite the confluence of Rattlesnake Run were the next downstream tributaries affected by mine drainage. The headwaters of Rattlesnake Run received small increments of mine drainage from three separate hilltop area strip mines. An abandoned drift mine located at the headwaters of the unnamed tributary contributed an acid load of 250 lb/day. The area immediately above the drift mine had been strip mined, however, it was dry. Mine No. 4526 is identified as a principal source.

Step Run

Step Run receives only moderate amounts of mine drainage. Total discharges amounted to 30 gpm which carried an acid load of 111 lb/day. The inventoried sites included two strip mines, one abandoned gas well, and one sealed drift mine.

On the bank opposite the confluence of Step Run, two abandoned gas wells discharged an acid load of 233 lb/day to a small unnamed tributary of Paint Creek.

Paint Creek-Main stem

In the community of Huefner a gas well located on the east bank of main stem Paint Creek discharged an acid load of 19 lb/day (No. 4254). Although not excessively high in acid load, this discharge had an iron concentration of 37 mg/l and imparted very noticeable discoloration to the stream.

On the east bank hill above Huefner seven drift mine openings and one small strip mine were investigated. The mines contributed a total acid load of about 100 lb/day. However, none of the discharges exceeded one gallon per minute, and within a short distance of their origin the discharges seeped back underground.

Mahles Run

Mahles Run is another tributary which was only moderately affected by mine drainage. Two drift mines and one gas well contributed small acid loads during the survey period. The total acid load from these three sources was 74 lb/day. Several additional drift mines were inspected but no discharges were found.

Paint Creek-Main stem

North of the community of Arthurs, three discharges whose exact origin is unknown, were located along the east bank of Paint Creek. The discharge points may result from abandoned oil or gas wells or may serve as drainways to underground mines located elsewhere. Extremely heavy deposits of "yellow boy", in places exceeding 3 feet in depth, surround the discharge points. The combined discharges totalled 73 gpm and carried combined acid loads of 610 lb/day. Two of these sources, No.'s 4506 and 4507, are classified as principal sources.

Little Paint Creek

Little Paint Creek is the last downstream tributary to Paint Creek which was affected by mine drainage. At Mine No. 4253 a discharge of 18 gpm was draining from an old drift mine portal. The acidity concentration of 9,235 mg/l and the acid load of 1,994 lb/day emanating

from this mine were the highest encountered in the Deer Creek watershed. An area strip mine is located immediately above this drift mine, however, it was dry.

Approximately 0.3 mile south of Mine No. 4253, another principal drainage source was located. Mine No. 1043 is located at the northern tip of a small contour strip mine and contributed an acid load of 837 lb/day.

Seepage from an area strip mine located near the headwaters of Little Paint Creek contributed an additional acid load of 193 lb/day.

This tributary also has the problem of abandoned gas well discharges previously discussed under stream water quality (Page B-3).

DEER CREEK

Deer Creek drains those parts of the watershed lying west of Route 66 and south of Shippenville. The drainage area of Deer Creek above Paint Creek is 18 square miles; the remaining 11 square miles drain that area of the watershed below the confluence of Paint and Deer Creeks and the confluence of Deer Creek with the Clarion River.

Little Deer Creek-Judith Run

Little Deer Creek, Judith Run, and several unnamed tributaries which make up the headwaters of Deer Creek were all affected by mine drainage.

Near the headwaters of Little Deer Creek three drift mines (each associated with strip mines) and one area strip mine were inventoried. The combined acid load from the four sources was 101 lb/day.

On Judith Run three surface mine operations and several drift openings within the strip mined area were investigated. A combined acid load of 545 lb/day was measured at these sites. Mine No. 4328 contributed 222 lb/day of this total. This was a strip operation which appeared to have destroyed or covered older underground operations. A gas well located downstream of the mining activity discharged an additional acid load of 888 lb/day. There are two well sites located adjacent to the stream bed at this site, however, only one was discharging. In addition, this gas well (No. 4337) discharged an iron load of 261 lb/day to Judith Run. Both Mine No. 4328 and gas well No. 4337 are classified as principal sources.

Deer Creek above Paint Creek

The headwaters of Deer Creek were immediately degraded by acid

mine drainage from numerous sources. Four surface mines and the remains of numerous underground sites were examined in this area. Mine No. 4325, a stripped out drift mine, contributed an acid load of 309 lb/day. Piles of mine refuse and slumps in the highwall indicate that there were at least three openings in the immediate area. The western end of the strip operation was active during the survey, however, no discharges were located. Mine No. 4324 contributed an additional acid load of 94 lb/day.

An unnamed tributary along the tracks of the Penn Central Railroad, south of the above area, was also affected by mine drainage. Several acid strip mine ponds within the disturbed area were sampled but the ponds had no visible surface discharge. Strip mine No. 4336 was the only mine site with a measurable discharge. At the source an acid load of 25 lb/day was discharged to the tributary.

An active coal preparation plant was also located in this area (No. 4321). At the time of the survey the discharge from the final settling pond of the plant contributed an acid load of 324 lb/day. When inspected the discharge from the pond was measured at 60 gpm, however, this is not likely a constant rate.

Deer Creek below Paint Creek

Mine operations below the confluence of Paint Creek and Deer Creek were primarily limited to the hilltop divide separating the Deer Creek and Clarion River drainage areas. Several mining areas were examined on the western side of Deer Creek, however, none of the sites were discharging.

On the east bank of Deer Creek several underground mines and numerous hilltop area strip mines were inventoried. There were several active surface mine operations in this area during the survey. Mine No. 4348 discharged a flow of 25 gpm from an old mine seal. One of the active strip mines was in operation immediately above this old seal. Three acid strip mine ponds were sampled, however, they had no visible surface effluent. Mine No. 4343, an abandoned strip mine, contributed the last acid discharge inventoried in the watershed. At this point a one gpm seepage area at the bottom edge of the strip mine spoil piles discharged an acid load of 23 lb/day to Deer Creek.

DISCUSSION

Deer Creek and many of its tributaries are grossly polluted by coal mine drainage. The streams are acidic, highly mineralized, and

devoid of normal aquatic life. The entire length of main stem Deer Creek is so affected.

Table 8 presents an area breakdown of mine drainage in terms of the total flow and total loadings (lb/day) of polluting constituents discharged to receiving streams in the Deer Creek watershed.

Acidity

From Table 8, a total acid load of 5.4 tons per day was discharged from the 59 sources draining at the time of study. The major portion of the mine acid was discharged to Paint Creek, Little Paint Creek, and their respective tributaries.

An average acid load of 6.9 tons per day was measured in Deer Creek downstream of all mine drainage inflow during the 1966 stream sampling program (Table 7). During this period the acid load measured at the mouth of Deer Creek ranged from a minimum of 10,032 lb/day (which closely approximates the sum of the individual mine sites) to a maximum of 17,718 lb/day.

This wide variance in acid load values found in the Deer Creek watershed is attributable mainly to periods of differing hydrologic conditions and small increments of mine acidity not directly measurable and therefore not specifically documented in the field inventory. It is particularly difficult to obtain accurate load values from surface mine areas during periods of high flow conditions. Spoil piles remaining at the mine sites store water and discharge their effluents at widely varying rates.

Alkalinity

Only four of the 59 discharges inventoried in the watershed contained alkalinity concentrations in excess of acidity concentrations. Three of these four discharges resulted from abandoned gas wells. Alkalinity concentrations of all stream sampling points located in the watershed were depleted to zero.

Hardness

A total of 3.3 tons per day of hardness was discharged to streams of the watershed by the sources measured. This value represents approximately one-third of the total hardness measured at the mouth of Deer Creek during the 1966 survey.

The highest hardness concentration encountered in the watershed was 3,040 mg/l from Mine No. 4501, an abandoned strip mine.

50a



FIGURE 6
DEER CREEK WATERSHED
SOURCES OF MINE DRAINAGE POLLUTION

B

Table 8

Mine drainage loadings
Deer Creek watershed

Receiving Stream	Stream Mile 1/	Drainage Area (sq. mi.)	No. of Mine Discharges	Total Discharges (gpm)	Total Net Acidity (lb/day)	Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Deer Creek	-	-	2	61	404	447	857	31	11
Tribs to Deer Creek	-	-	9	95	608	355	926	143	21
Paint Creek	5.8	39.9	7	108	816	865	3,690	468	23
Tribs to Paint Creek	-	-	17	779	4,483	2,486	6,752	477	137
Frills Run	16.3	1.3	1	120	619	936	1,612	333	43
Little Paint Creek	7.9	6.2	4	30	2,193	304	2,834	298	26
Tribs to Little Paint Creek	-	-	1	1	0	1	1	0	0
Judith Run	4.0	3.5	5	117	1,275	1,005	2,252	299	38
Tribs to Judith Run	-	-	2	6	158	37	167	38	2
Step Run	13.9	6.3	4	30	111	107	248	12	4
Mahles Run	12.1	4.9	3	48	74	59	123	14	1
Little Deer Creek	3.3	6.2	4	8	101	34	122	6	4
TOTALS			59	1,403	10,842	6,636	19,584	2,119	310

1/ Distance above mouth of Deer Creek.

Ions in coal mine drainage contributing to hardness in significant amounts are calcium, magnesium, iron, manganese, and aluminum.

Sulfate

Acidic and alkaline mine water both commonly contain high concentrations of sulfate ion. The sources of sulfate in these mine effluents are sulfuric acid and dissolved sulfate salts. The sulfate content of receiving streams draining coal mining areas is indicative of the amount of total acidity that has been discharged to them through mine drainage. This sulfate content is the residual component of neutralized acidity as well as a component of acidity not yet subjected to neutralization.

A total sulfate load approaching 10 tons per day was measured in the study area. The average sulfate load measured at the mouth of Deer Creek during 1966 was nearly 14 tons per day.

The highest sulfate concentration encountered during the study was 11,375 mg/l from Mine No. 4253, an abandoned drift mine.

Total Iron

Approximately one ton per day of iron was measured at the individual mine or gas well sites. This load is about 4 times as great as the iron load measured at the mouth of Deer Creek. This difference is attributed to the large amounts of iron which are deposited along the stream banks and on the stream bottom. This precipitation is noticeably evident in many streams of the watershed as they acquire the stain and sediment characteristics of "yellow boy" pollution.

The highest iron concentration encountered in the watershed was 1,450 mg/l from Mine No. 4501, an abandoned strip mine.

Manganese

Similar to the occurrence of other mine drainage related parameters, manganese concentrations are excessive at all stream sampling stations shown in Table 7.

A total of 510 lb/day of manganese was measured at the mining sites.

Table 9 presents a summary of flow volumes and chemical loadings, by type of source, for the 59 discharging sources inventoried.

Table 9

Mine discharge loadings
Bear Creek watershed

Source Type	No.	Total Discharges (gpm)	Total Net Acidity (lb/day)	Total Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Drift Mines (abandoned)	17	69	3,622	551	4,360	357	59
Combination Drift Mines 1/	9	55	745	470	1,137	150	25
Strip Mines (abandoned)	15	44	1,197	437	2,541	291	42
Combination Strip Mines 2/	2	4	69	46	114	9	3
Coal Preparation Plant (active)	1	60	324	442	734	26	10
Unknown Sources	3	73	610	609	1,172	318	11
Oil Wells (abandoned)	1	25	60	100	180	11	3
Gas Wells (abandoned)	11	1,073	4,215	3,981	9,146	957	157
TOTALS	59	1,403	10,842	6,636	19,584	2,119	310

1/ Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the underground mine.

2/ Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the surface mine.

At the time of the survey there were several active surface mine operations in the watershed. There were no active underground mines. The only discharge from an active operation was the coal preparation plant (No. 4321, acid load, 324 lb/day).

Inactive or abandoned drift mines and abandoned gas wells were the principal sources of acid pollution. These sources were responsible for 72 percent of the total mine acidity measured in the watershed. However, there are additional major sources of acid pollution not restricted to the above categories.

The 17 drift mines and 11 gas wells (Table 9) contributed the following percentages of each parameter: Flow (gpm), 81 percent; net acidity, 72 percent; hardness, 68 percent; sulfate, 69 percent; total iron, 61 percent; and manganese, 69 percent.

POLLUTION ABATEMENT

From the preceding discussion it is apparent that particular pollution abatement emphasis will have to be placed upon abandoned drift mines and gas well sources. Since more than 70 percent of the total watershed acidity emanated from these sources, abatement within these two source categories should effect significant water quality improvement in the Deer Creek watershed.

Although drift mine and gas well sources within the watershed contribute more than 70 percent of the total acid load, these sources total 28 and do not include significant discharge points of a different source type. The recommended principal source approach to pollution abatement selects drainage sites with respect to the magnitude of their acid loads and the relative contribution of each source to the total watershed problem. Thus, a reduced number of sources can be selected for abatement.

For a preliminary pollution abatement program on Deer Creek, 13 sources have been selected. These 13 sources accounted for 81 percent of the total measured watershed acidity. This approach requires abatement of 15 fewer sources and includes all significant sources of acid pollution irrespective of source type.

Abatement by source type (28 sources) would be equally successful in removing acidity from the streams of the watershed, however, due to the exclusion of significant acid discharges of a different source type, several areas of water quality concern would remain in the watershed.

In order to predict the stream effect resulting from mine drainage

pollution control, it is necessary to select a critical chemical parameter on which calculations may be based. Since Deer Creek is a consistently acid stream and no industrial acid sources are known in the basin, and acidity is usually considered the single most harmful property of coal mine drainage, total stream acidity is used in this discussion to predict water quality improvement. Similar reduction in other mine drainage parameters (hardness, sulfate, iron, manganese) are expected to be coincident with acidity reduction.

PRINCIPAL SOURCES

Thirteen sites are identified as principal watershed pollution sources. These sources consist of two drift mines, one coal preparation plant, and six gas well effluents. The only discharge from an active source was the coal preparation plant.

In the Deer Creek watershed all sites which contributed an acid load in excess of 200 lb/day are considered as principal sources.

The combined acid load of the principal sources was 8,748 lb/day, about 81 percent of the total measured acidity (Table 10).

In view of the present technical unknowns involved in the abatement of mine drainage, present methods cannot always be expected to reach a maximum degree of effectiveness. There are at least three of the principal sources which involve both surface and underground operations in combination (Mine No.'s 1043, 4325, 4328). A 75 percent reduction in acid loads from these three sources and the two drift mines (No.'s 4253, 4526) might be a reasonable expectation.

Abatement of strip mine No. 4520, provided there are no interconnections with underground workings, should be expected to reach a near maximum degree of efficiency. A 90 percent reduction in acid load at this mine site should result in even greater total acidity reduction than that which is assumed (90 percent). This is due to numerous seepage areas about the perimeter of the strip operation. While individually these seepage areas are only minor sources of stream acidity, cumulatively these same areas are capable of producing significant amounts of combined total acidity. Acidity reductions through abatement techniques at these additional points is expected coincident with abatement of the major source site.

Abatement of gas well effluents are assumed to attain a maximum degree (100 percent) of effectiveness. Some of the sites may require only plugging or capping of the existing well casing while others may require the installation of new casing before sealing. Abatement of such sites as No.'s 4506 and 4507 are also included in this category. It is possible that these sources may not result from abandoned oil

Table 10

Principal mine drainage sources
Deer Creek watershed

Mine No.	Source Type	Flow (gpm)	Specific Conductance	Acidity mg/l	Receiving Stream
1043	Drift mine combination ^{1/}	16	6,000	4,360	837
4253	Drift mine	18	8,000	9,235	1,994
4321	Active coal washery	60	1,600	450	324
4325	Drift mine combination	10	1,200	2,589	309
4328	Strip mine combination ^{2/}	7	5,100	2,650	222
4520	Strip mine	7	6,500	4,270	358
4526	Drift mine	9	5,000	2,320	250
4337	Gas well	100	2,400	740	888
4516	Gas well	120	1,700	430	619
4531	Gas well	495	1,275	290	1,722
4532	Gas well	212	1,200	280	712
4506	Unknown	25	2,400	690	207
4507	Unknown	36	2,500	710	306
					8,748

^{1/} Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the underground mine.

^{2/} Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the surface mine.

^{3/} Specific conductance measured as micromhos/cm.

or gas wells, however, they bare more resemblance to such sites than they do the coal mine operations.

Through state regulatory control, abatement of the acid load from the active preparation plant should reach 100 percent.

Assuming the respective reductions in acid load from the above mentioned sources, over 7,800 lb/day of acid would be removed from the receiving streams of the watershed.

The principal source abatement approach outlined in this document (13 sources) should prove sufficient to significantly improve the water quality in the Deer Creek watershed. However, as previously stated there is insufficient water quality data available to accurately predict the cumulative effect of source abatement. A recommendation relative to the development of this necessary data is given on page 3. If future data development and economic or technical constraints prove the infeasibility of the principal source abatement approach, as outlined, it may be necessary to add or delete sources due to the development of more valid correlations between stream water quality and mine discharge characteristics. Until such a time the principal source approach can effectively serve as the first phase or priority in a program of mine drainage source abatement.

The following is a more detailed description of the 13 principal sources recommended in this document for mine drainage abatement. The locations of the principal source sites are shown in Figure 7.

Coal Mine Sources

Mine No. 1043

An acid load of 837 lb/day was discharged to an unnamed tributary of Little Paint Creek by Mine No. 1043. The small strip mine and associated drift mine is located almost at the top of a ridge near the head of the unnamed tributary.

Mine No. 4253

This mine was located on Little Paint Creek approximately 0.6 mile north of Mine No. 1043. The 18 gpm flow at this site discharged from an open drift mine mouth. Due to the minimal amount of refuse scattered about the mining site, the size of the mine appears limited. The 18 gpm discharge with an acidity concentration in excess of 9,200 mg/l contributed an acid load of 1,994 lb/day. This was the largest acid load measured in the entire Deer Creek watershed.

Mine No. 4321

A pipe discharge from the final settling pond of an active coal

washery at Billings contributed an acid load of 324 lb/day to Deer Creek. At the time of sampling the flow was measured at 60 gpm, however, this was probably not a constant rate and, like any other type of discharge, subject to wide variation.

Mine No. 4325

An unnamed headwater tributary of Deer Creek received an acid load of 309 lb/day from a stripped-out drift mine. The contour strip operation has destroyed at least three mine openings in the immediate area. Piles of mine refuse and slumps in the highwall mark the approximate location of these old openings. The western end of this strip operation was active during the survey. Treatment ponds were constructed at the operation site, however, there was no discharge at the time of inspection.

Mine No. 4328

A partially reclaimed strip mine in the headwater area of Judith Run discharged an acid load of 222 lb/day. The strip mined area is U-shaped and appears to have destroyed several old drift mine openings. The 7 gpm discharge at No. 4328 originated from a low point in the mined area at the southeast tip of the operation. Additional discharges inventoried in this strip mined area totalled 165 lb/day of acidity.

Mine No. 4520

Just north of Frills Corners a circular area strip discharged an acid load of 358 lb/day to the headwaters of Paint Creek. The area had been completely backfilled and graded to contour, however, no vegetation had been restored. The 7 gpm flow represented cumulative seepage from the base of the strip mine. The drainage course of the discharge was noticeably conspicuous due to the path of dead trees left behind. One additional acid discharge (127 lb/day) and numerous seepage areas were located along the strip mine perimeter.

Mine No. 4526

Approximately 2.5 miles northeast of Snydersburg a 9 gpm discharge from a slumped drift mine opening carried an acid load of 250 lb/day to an unnamed tributary of Paint Creek. The drift mine appears to have been of a very limited size. A small area strip mine is located immediately above this old opening, however, it was dry at the time of inspection.

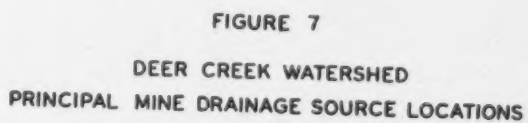
VICINITY MAP

LAKE ERIE

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Gas Well SourcesNo. 4337

This abandoned gas well discharge was located on Judith Run approximately 1.5 miles from its confluence with Little Deer Creek. There were two wells both located immediately adjacent to the stream bed. Only one well was discharging at the time of inspection. The 100 gpm effluent from this gas well carried an acid load of 888 lb/day to Judith Run.

No. 4516

An abandoned gas well was located near the headwaters of Frills Run just south of Lickingville. This 120 gpm discharge imparted the gross discoloration to Frills Run and was the only pollution source located in the drainage area. The discharge contained 333 lb/day of iron which accounted for the discoloration effect.

No.'s 4531, 4532

Two additional gas well discharges were located on the headwaters of an unnamed tributary to Paint Creek just south of Tylersburg. At the time of sampling these two effluents contributed the entire headwater flow of the tributary. In addition to the combined acid load of 2,434 lb/day discharged by these sources, they also imparted a high degree of discoloration to the tributary.

No.'s 4506, 4507

Three pollution sources whose exact origin is unknown were located in a small area adjacent to Paint Creek north of Arthurs. These sources have some similarity to abandoned oil and/or gas well discharges, or, they may serve as drainways to mines located elsewhere in the watershed. Extremely heavy iron deposits are associated with the discharge points. The effluents are located at approximately the same elevation and are spaced about 100 to 150 yards apart. Two of these sources, No.'s 4506 and 4507, discharged acid loads in excess of 200 lb/day. There were no indications of mining activity in the immediate area. However, storage tanks and pumping facilities from an abandoned oil yard were located about 0.3 mile upstream from the three discharge points. The acid loads carried by No.'s 4506 and 4507 were 207 lb/day and 306 lb/day, respectively. The additional source, No. 4505 contributed an acid load of 97 lb/day.

SUMMARY AND CONCLUSIONS

1. The Licking Creek watershed, draining 52 square miles of south-central Clarion County, has been severely degraded as a result of coal mine discharges. Both underground and surface mining methods have been employed in the watershed. Some of these workings are quite large and extend over many acres both above and below ground.
2. The degraded water quality of Licking Creek extends the entire length of the main stem as well as affecting many miles of tributary streams. The streams draining most of the coal mined areas are acidic, highly mineralized, and devoid of normal aquatic life.
3. Approximately 200 mining sites and an estimated 4,000 acres of strip mined area were investigated during the study. Samples for chemical analysis were collected from 143 discharging sources and more than 50 strip mine ponds. Discharges from the coal mine sources ranged from one to 90 gallons per minute (gpm) and totalled 1.58 million gallons per day (mgd). The pH values of the effluents ranged from 2.1 to 7.3 and total acidity concentrations as high as 5,070 mg/l were recorded. The total acid load (less alkalinity) discharged to Licking Creek and its tributaries equalled 6,314 lb/day.
4. There was only one active discharging mine at the time of the survey. This was a drift mine on Little Licking Creek which discharged an acid load of 27 lb/day. The largest single source of acid pollution (667 lb/day) in the watershed resulted from an abandoned gas well effluent in the community of Sligo.
5. Sixteen mine drainage sources are identified as principal watershed pollution sources. These sources consist of six strip mines, five drift mines, four combination underground mines, and one gas well. All of the effluents are from abandoned sites. The combined acid load of these 16 sources was 4,426 lb/day, 70 percent of the total acidity measured in the watershed.

DESCRIPTION OF AREA

The headwaters of Licking Creek rise in south-central Clarion County east of the community of Curllsville. The stream flows generally west some 12 miles to its confluence with the Clarion River at mile point 14.8. The watershed is rhombic in shape and drains

52 square miles of Clarion County.

The topography of the Licking Creek watershed is less rugged than that found in the other inventoried watersheds of the Clarion River basin. Generally, the valley bottoms widen and hillside slopes become less steep and abrupt. Hilltop elevations seldom exceed 1,500 feet above sea level.

Cherry Run is the principal tributary to Licking Creek and drains 21.3 square miles (41 percent) of the total 52 square mile watershed area. Sligo is the largest community lying totally within the watershed boundary with a 1960 population of 815. Rimersburg, which is located on the basin boundary had a 1960 population of 1300.

The Licking Creek drainage area is bounded on the north by the Clarion River, on the west by the Allegheny River and minor Allegheny River tributaries, on the south by Redbank Creek, and on the east by Piney Creek.

The Licking Creek watershed has been extensively mined. Numerous deep mines have been located throughout the watershed, however, later stripping operations have destroyed the majority of these old deep mine sites. This watershed contains more unreclaimed strip mine acreage than any of the other inventoried Clarion River watersheds. This is partly attributable to the greater number of acres disturbed by strip operations but it also appears that much of this stripping was performed at a time when only minimal reclamation was required.

STREAM WATER QUALITY

Licking Creek, principal tributaries to Licking Creek, and numerous unnamed tributaries within the watershed are seriously polluted by coal mine drainage. This degraded water quality is evident from the uppermost reaches of the watershed and persists over the entire downstream length. The affected streams of the watershed are acidic, highly mineralized, and devoid of normal aquatic life.

During the course of the field study several stream locations (Table 11) were sampled for chemical analysis. These stations were selected to measure the cumulative effects of mine drainage in the receiving streams. Additionally, stream sampling data collected near the mouth of Licking Creek during the 1966 stream sampling program are included. A summary of all stream data is presented in Table 12. In conjunction with sampling and flow measurements at selected stream

Table 11

Stream water quality sampling stations,
Licking Creek watershed

<u>Station No.</u>	<u>Sampling Period</u>	<u>Stream</u>	<u>Location</u>
4589	Oct. 1967	Little Licking Cr.	Near Mouth
4590	Oct. 1967	Mineral Run	Near Mouth
4591	Oct. 1967	Anderson Run	Near Mouth
4592	Oct. 1967	Cherry Run	Near Mouth
4593	Oct. 1967	Licking Creek	Near Mouth
4595	Oct. 1967	Craggs Run	Near Mouth
0513	June, Aug., Sept. 1966	Licking Creek	Near Mouth

Table 12
Stream water quality, Licking Creek watershed

Station No.	No. of Samples	Flow (gpm)	Specific Conductance	Total Acidity mg/l	Total Hardness mg/l	Sulfate lb/day	Total Iron mg/l	Manganese lb/day					
				lb/day	lb/day	mg/l	lb/day	mg/l					
4589	1	594	3,000	570	4,062	210	1,496	1,720	12,260	116	827	44.0	314
4590	1	351	3,250	880	3,706	1,144	4,818	1,872	7,884	139	586	42.4	179
4591	1	239	1,750	470	1,347	820	2,351	1,400	4,015	13	37	34.4	99
4592	1	1,701	1,500	256	5,226	616	12,573	624	12,737	6	131	10.8	220
4593	1	4,460	2,200	355	18,999	760	40,675	990	52,984	15	803	21.6	1,156
4595	1	747	970	-48	-430	436	3,908	300	2,689	2	14	5.6	50
0513 ^{1/}	6 ^{2/}	4,275	2,092	346	16,850	785	38,246	645	22,661	17.7	1,039	24.5	1,140

^{1/} Additional sampling of Station No. 4593, conducted prior to the mine drainage source investigation.

^{2/} Average of 6 samplings, 1966

^{3/} Specific conductance measured as micromhos/cm.

locations, pH and specific conductance determinations were made at a number of additional stream locations in the watershed. These values and the locations of the stream sampling stations are shown in Figure 8.

Station No. 4589

Little Licking Creek is continuously polluted by mine drainage discharges over its entire length. At its mouth the stream carried a residual acid load exceeding 2 tons per day (Table 12). Sulfate, iron, and manganese concentrations at this point were among the highest encountered at stream sampling locations in the watershed. Much of the iron loading discharged to Little Licking Creek is precipitated to the stream bed and along the stream bank resulting in noticeable discoloration.

Station No. 4590

The ratio of source acid load per square mile of drainage area on Mineral Run was the highest encountered in the watershed. An acidity loading of 3,706 lb/day was measured at the mouth of Mineral Run (Station No. 4590). This loading value is an approximately three-fold increase over the source acid load of 1,200 lb/day. This difference is primarily attributable to the many seepage areas which occur at the bottom edges of the unreclaimed strip mined areas. Many of these strip areas are located almost at the same elevation as the creek itself.

Station No. 4591

Anderson Run is another watershed tributary seriously affected by mine discharges. The acid load measured near the mouth was 1,347 lb/day, almost double the source acid load measured at the mining sites.

In addition to acidity, other mine drainage related parameters such as hardness, sulfate, and iron were also high.

Station No. 4592

Cherry Run is the principal (largest) tributary to Licking Creek and drains 21.3 square miles of the total 52 square mile Licking Creek watershed. Over 5,000 lb/day of unneutralized acidity was measured near the mouth of Cherry Run. The sum of the individual source loads was only 1,746 lb/day. The difference is partly attributable to the varied hydrologic periods under which the source investigations and stream sampling was performed, however, the difference is mainly

attributable to the numerous seepage areas both above and below ground which occur over the entire 21.3 square mile drainage area.

Station No. 4595:

Craggs Run was the only named tributary in the Licking Creek watershed which was alkaline. At its mouth, Craggs Run had a pH of 6.4, an acidity concentration of 0 mg/l, and an alkalinity concentration of 48 mg/l. Although alkaline, the stream was influenced by mine drainage as evidenced by sulfate and hardness concentrations of 300 mg/l and 436 mg/l, respectively.

Station No. 0513, 4593

During the 1966 stream sampling program, Licking Creek at its mouth carried excessive amounts of all mine drainage related parameters. An average acidity loading of nearly 8.5 tons per day was discharged to the Clarion River (Table 12). The minimum acid loading during the 1966 survey was 4 tons per day while the maximum value was over 13 tons per day. The total acid load from the individual discharging mine sites was 3.1 tons per day.

In addition over 11 tons per day of sulfate was discharged to the Clarion River by Licking Creek.

BIOLOGY

A biological evaluation of Licking Creek at Station No.'s 4593 and 0513, Licking Creek near mouth, was conducted during 1966 to determine the effect of pollution upon normal aquatic fauna. The benthic organisms collected consisted almost entirely of acid-tolerant forms. The substrate of the stream showed physical evidence of mine drainage pollution which included red stains on rocks, sediment characteristics, and lack of biological growths.

In summary, all mine drainage-affected stream locations, except Craggs Run, are characterized by pH values below 3.5 and specific conductance values above 1,500 micromhos/cm. Alkalinity concentrations were depleted to zero and acidity concentrations ranged from 260 mg/l to 880 mg/l.

Most of the watershed streams draining mined areas are characterized by a red appearance and/or the presence of an orange-yellow precipitate in suspension or on the stream bottom. During

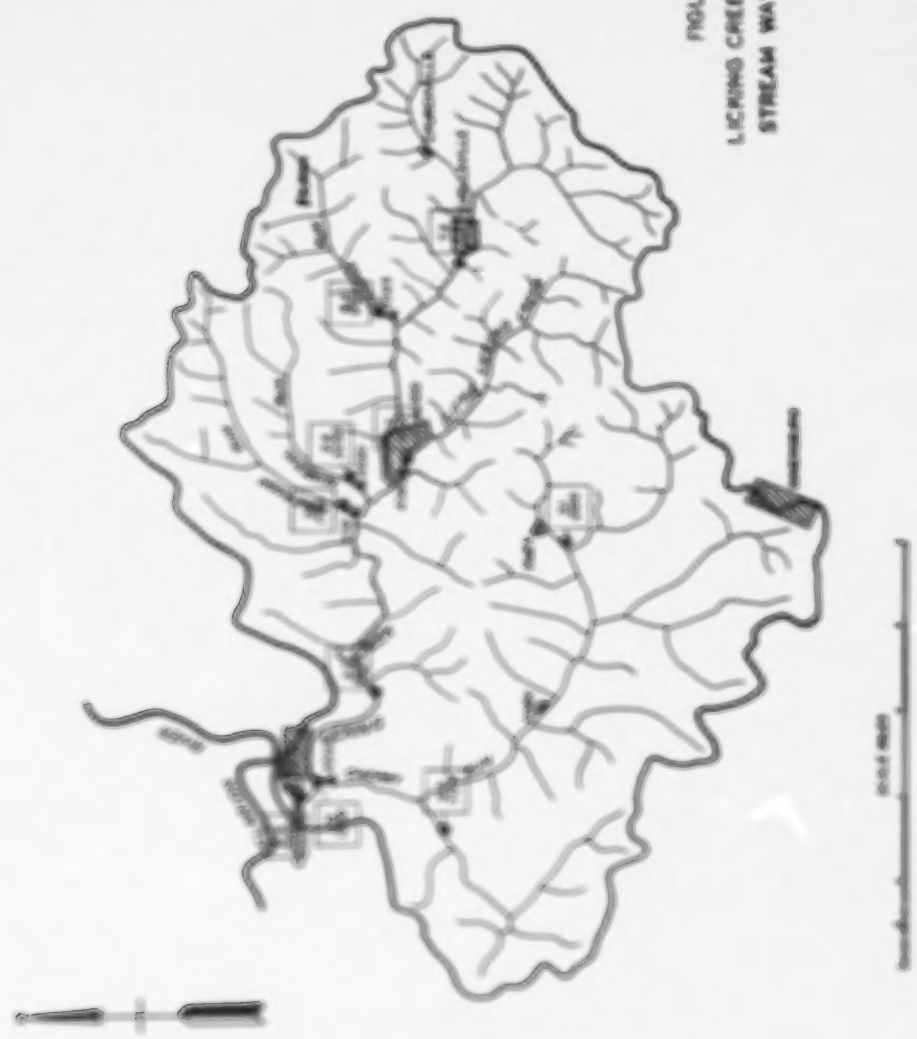
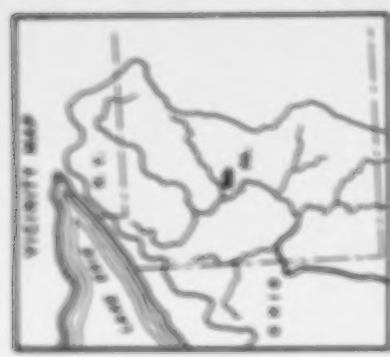


FIGURE 6
LICKING CREEK WATERSHED
STREAM WATER QUALITY

periods of high stream runoff, the streams become extremely turbid due to flushout and resuspension of stream bottom deposits which result from drainage of mined areas.

SOURCES OF MINE DRAINAGE

Approximately 200 mining sites and an estimated 4,000 acres of strip mined area were investigated during this study. Samples for chemical analysis were collected from 143 sources discharging at the time of the survey. Discharges from coal mine sources ranged from one to 90 gpm. The total effluent volume was 1,095 gpm or 1.58 mgd. The pH values of the effluents ranged from 2.1 to 7.3 and total acidity concentrations as high as 5,070 mg/l were recorded. Only 15 of the discharging sources were alkaline.

In addition to the 143 discharging sources, over 50 abandoned strip mine ponds were also sampled for chemical analysis. All but 5 of these ponds were acidic in nature. While these ponds contributed no visible surface effluents, they undoubtedly contribute acidity to the streams by overflow during periods of wet weather, sub-surface flow during periods of normal stream flow, and continual seepage through the surrounding spoil piles.

A description of the mine drainage sources in the Licking Creek watershed follows. All mine location sites inventoried in the watershed are shown in Figure 9 following the source description section. Mine drainage data is shown in Appendix D.

Headwaters

The headwaters of Licking Creek rise southeast of the community of Ourilsville, and flow generally west toward the community of Sligo. Approximately fifteen strip mine operations and five underground mines were inventoried in this headwaters area. However, the above strip mines have destroyed or covered additional underground mine openings.

There were only two major point sources of acid discharge located in the headwaters of Licking Creek. These were Mine No.'s 4314 and 4317 which discharged acid loads of 243 lb/day and 347 lb/day, respectively. These two sources were located side-by-side in a large underground and surface mined area north of Ourilsville. There was one additional major discharge point (Mine No. 4316) located in this mining complex, however, its discharge drained to Craggs Run, the first named tributary to Licking Creek. All three sources are classified as principal watershed pollution sources and are identified in a

later section of this document.

Although there were only two major sources of mine drainage pollution inventoried in the headwaters of Licking Creek, the water quality of this area was severely degraded. This water quality degradation resulted from severe leaching or seepage of both ground and surface waters through the numerous ungraded spoil and refuse piles which abound in the area. Similar occurrences were common throughout the entire Licking Creek drainage area. A total of fifteen strip mine ponds were sampled in the headwaters of the watershed.

Craggs Run

Craggs Run, which joins the main stream east of Sligo, was the only major tributary located during the source inventory which exhibited alkaline conditions. A total of 222 lb/day of acidity was discharged to this tributary watershed by eight discharging coal mine sources. The majority of these discharges result from the above mentioned underground and surface mined area located on the divide separating the Craggs Run and Licking Creek drainage areas. Mine No. 4316 discharged an acid load of 112 lb/day and is identified as a principal watershed source. The remaining acid load of 110 lb/day was contributed by seven individual sources, five strip mines and two drift mines.

Little Licking Creek

Little Licking Creek drains the southeast area of the watershed and joins the main stream in the community of Sligo.

Fourteen coal mine sources and one abandoned gas-well effluent were inventoried in this 5.4 square mile drainage area. The total acidity loading from all sources was 1,466 lb/day. Approximately 65 percent of this load value was contributed by two sources; Mine No. 4485 and No. 4491, the abandoned gas well.

The 12 gpm effluent from the abandoned gas well is located at Sligo and at inspection discharged an acid load of 66¹/₂ lb/day to Little Licking Creek. In terms of acidity loading this was the largest acid discharge encountered in the entire Licking Creek watershed.

Mine No. 4485 is located southeast of Sligo on the hillside above main stem Little Licking Creek. The area around the discharge point had been recently strip mined. The acid load discharged by this source was 427 lb/day.

Mine No. 4424 was an active drift mine located within an abandoned strip mine operation. At the time of the source inventory the mine had an untreated discharge of 8 gpm and carried an acid load of 27 lb/day. This was the only active underground mining operation in the entire Licking Creek drainage area. There were several active stripping operations in the Little Licking Creek drainage area, however, they contributed no acid load.

Mineral Run

Over 1200 lb/day of acidity was discharged to this two square mile tributary watershed from seven mine sources. Five of the discharges resulted from drift mines and contributed 967 lb/day of acidity. Three of these drift mines (No.'s 4570, 4568, 4567) have been stripped out by later surface mining operations. Mine No. 4572 discharged an acid load of 199 lb/day. The area has been strip mined and reclaimed, however, an effluent of 5 gpm discharges from the bottom edge of the reclaimed area. It is not known whether the strip mine destroyed older underground openings, but it is known that much of the surrounding area has been undermined. The last discharge on Mineral Run was Mine No. 4571, which was a stripped out underground mine that discharged an acid load of 45 lb/day.

Mine No.'s 4566, 4567, 4568, 470, and 4572 are classified as principal watershed pollution sources.

In addition to the seven inventoried mine sources on Mineral Run, there were numerous areas of seepage that also contributed significant amounts of acid. Along the perimeters or base lines of the strip mined areas there were wet spongy areas which contributed these unknown amounts of acidity to the receiving tributaries. This was particularly noticeable in areas where unreclaimed strip mine spoil piles absorbed surface-water runoff. This water then becomes acidic while percolating through the spoil banks and is finally discharged at the base of the bank over wide areas.

Anderson Run

Anderson Run drains a three square mile area north and northeast of Sligo. Extensive surface mining has been done in the upper areas of the tributary. Some underground mines have also been located in this area, however, the strip mine operations have destroyed or covered all but a few of the underground openings.

Twenty-six strip mines and one drift mine combination were inventoried during the field study. These operations contributed a combined acid load of 787 lb/day to the tributary watershed.

All but three of the 26 discharging mines contributed only minor amounts of acidity (<30 lb/day). Mine No.'s 4599, 4564, and 4552 were the principal sources of acid mine discharge in the Anderson Run drainage area. The acid loads were 242 lb/day, 154 lb/day, and 78 lb/day, respectively.

Mine No. 4599 is located near the mouth of Anderson Run. The discharge from this mine resulted from cumulative seepage below the reclaimed strip area. The 8 gpm effluent from Mine No. 4564 resulted from overflow of an abandoned strip pit pond located in the final cut of the unreclaimed strip mined area. The pond overflow was piped under a haulage road in the mined area and then into Anderson Run.

Both Mine No.'s 4599 and 4564 are identified as principal watershed pollution sources in a later section of this document.

The 78 lb/day acid load of Mine No. 4552 was discharged to a small unnamed tributary of Anderson Run. A large contour stripping operation is located at the headwaters of the tributary. There were no direct discharges to the tributary from the stripping operation, however, the gradual accumulation of seepage which eventually reaches the tributary completely degrades the water quality over the entire length of the tributary.

Main Stem

Below the confluence of Anderson Run and the downstream confluence of Cherry Run, only minor amounts of mine acidity were discharged to main stem Licking Creek. There were several abandoned strip mines located on both banks of Licking Creek, however, the only effluents inventoried during the survey resulted from seepage points located at the base of the strip mine spoil banks.

Cherry Run

Main stem Cherry Run is formed by two headwater tributaries which meet near the Cherry Run Campground west of the community of Huey. The headwater tributary which drains the southern most part of the Cherry Run area rises northwest of Rinersburg and is immediately degraded by mine drainage. Approximately 30 minor sources of mine drainage acidity were located in the drainage area of this tributary. Four of the sources were non-discharging strip mine ponds while the remainder of the sources consisted almost entirely of small seepage areas located below the strip mined areas. No major sources of acid pollution were located.

The second headwater tributary of Cherry Run rises east of the community of Huey and was immediately degraded by mine drainage. A contour strip mine located at the headwaters of this tributary was responsible for the degraded condition of the tributary. At this point the pH of the tributary was 3.2 and the conductivity exceeded 1,000 micromhos/cm. In addition to numerous minor acid discharges received by the tributary, there are two principal acid pollution sources (Mine No.'s 4476, 4477) located south of Huey.

Discharge No. 4476 represents the entire flow of a small unnamed tributary flowing through the mined area. In addition to spoil pile seepage there were several drainage points resulting from underground mine openings destroyed by the strip mine operation. The 85 gpm flow was sampled below the disturbed area and carried an acid load of 372 lb/day.

Mine No. 4477 is located approximately 0.2 mile north of Mine No. 4476 in the same strip mine operation. Seepage from both surface and underground mines was impounded in a strip cut. An 85 gpm effluent overflowed the small impoundment and drained to the unnamed tributary. The acid load was 448 lb/day.

Main Stem

Below Huey, and the next principal downstream tributary, the main stem receives numerous small discharges of mine acidity. As is common over the entire watershed the majority of these discharges resulted from seepage areas around strip mines. The only major source of acid load was from Mine No. 4412.

Mine No. 4412 is a drift mine located in a strip mine highwall. The 6 gpm effluent from the drift opening carried an acid load of 123 lb/day to the receiving stream. In addition to this discharge, two seepage areas were sampled which totalled an additional acid load of 45 lb/day.

A large unnamed tributary joins Cherry Run approximately 1.2 miles above the confluence of Cherry Run and Licking Creek. Numerous abandoned strip mines, several inactive drift mines, and two active strip mines were located within the drainage area of this tributary. Despite the extensive mining activity the water quality of the tributary was not severely degraded by mine drainage. The pH of the tributary ranged from 6.2 to 7.4 while conductivity values remained generally below 750 micromhos/cm.

The last area of mining in the Licking Creek watershed was located on the west bank of Cherry Run just south of the confluence

of Cherry Run and Licking Creek. At this location an area strip mine has destroyed an older underground mine. The discharge from Mine No. 1227 consisted of two effluents from the base of the spoil piles. The two discharges merged below their point of origin, were piped under the county road and then discharged to Cherry Run. The total volume of the effluent was 40 gpm and it carried an acid load of 196 lb/day.

DISCUSSION

Licking Creek and many of its tributaries are grossly polluted by coal mine drainage. The streams are acidic, highly mineralized, and devoid of normal aquatic life. The entire length of main stem Licking Creek is so affected.

A total of 143 discharging sources and approximately 60 strip mine ponds were sampled for chemical analysis. The total measured discharge volume was 1,095 gpm or 1.58 mgd. Table 13 presents an area breakdown of mine drainage in terms of the total flow and total loadings (lb/day) of polluting constituents discharged to receiving streams in the Licking Creek watershed.

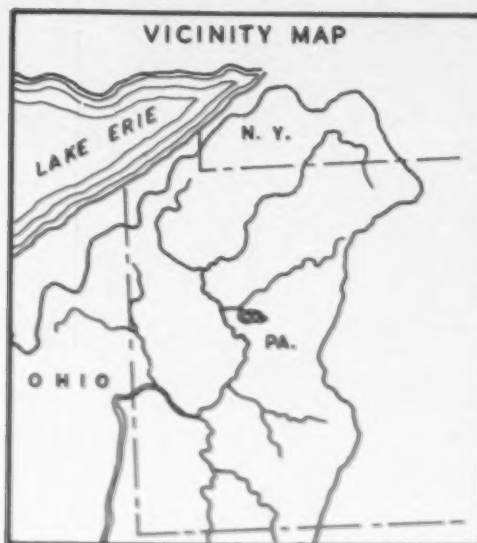
Acidity

From Table 13, a total acidity loading of 6,314 lb/day was discharged from the 143 sources draining at the time of study. The major part of the mine acidity was discharged to Cherry Run, Little Licking Creek, Mineral Run, and their respective tributaries.

An average acidity loading of nearly 8.5 ton per day was measured in Licking Creek downstream of all mine drainage inflow during the 1966 stream sampling program. This average loading is some 5.3 tons per day greater than the sum total of the individual discharging mine sites (Table 13). This large difference in acid loads does not necessarily reflect failure to locate and sample all sources of watershed acidity, rather it demonstrates the impracticality of making valid correlations between stream loading values and the load values obtained by totalling the individual sources. Such comparison does not allow for the acid contribution of the numerous immeasurable seepage areas in the watershed nor can such a comparison account for the in-stream acidity produced by hydrolysis of the effluent below the point of origin. During the 1966 sampling program the acid load measured at the mouth of Licking Creek ranged from a minimum of 8,096 lb/day to a maximum of 26,143 lb/day. Any initial survey of mine drainage conducted during a relatively short period of time is severely restricted in attempting to obtain

7/a





- ① ABANDONED GAS WELL
- UNDERGROUND MINE
- ② SAMPLED POINT LOCATION
- WINE REFUSE
- STRAW WINE

FIGURE 9
LICKING CREEK WATERSHED
SOURCES OF MINE DRAINAGE POLLUTION

Table 13

Mine drainage loadings
Licking Creek watershed

Sampling Station	Station No. & Date	Drainage Area (ac., sq. ft.)	No. of Mine Discharges	Total Discharges (gpm)	Total Net Acidity (lb/day)	Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Licking Creek	"	"	7	79	389	356	757	67	14
Station on Licking Creek	"	"	16	60	493	483	1,051	17	22
Shavers Fork	400	21.3	20	115	623	1,265	1,723	15	23
Station on Shavers Fork	"	"	46	461	1,323	4,063	5,911	192	72
Station on Licking Creek	5,400	3.4	12	132	1,371	1,723	2,890	256	63
Station on Licking Creek	"	"	3	19	95	135	227	2	5
Shavers Fork	3,000	3.0	14	58	606	589	1,428	29	25
Station on Shavers Fork	"	"	12	40	179	331	457	4	9
Shavers Fork	3,000	3.0	6	84	1,014	726	1,884	62	32
Station on Shavers Fork	"	"	1	35	197	300	462	6	9
Shavers Fork	1,000	3.0	1	3	112	42	162	19	3
Station on Shavers Fork	"	"	7	19	110	137	232	4	6
TOTAL					6,314	10,150	17,184	673	283

Station above mouth of Licking Creek

representative runoff flow rates and acid source discharge volumes. This is due to the hydrologic fluctuations occurring during the study period. This is of particular importance in the Licking Creek watershed due to the thousands of acres of unreclaimed strip mined lands. Many areas of the watershed somewhat resemble a sponge with large red-colored seepage areas visible over large land areas.

One possible additional source of unchecked acidity in the watershed may result from the effluents of abandoned gas wells. Only one such well site (No. 4491) was sampled in the watershed. The acid load carried by this source was 67 lb/day, the highest acid load encountered in the entire watershed. Any gas well effluents located during the normal course of mine investigations were sampled, however, no detailed effort was made to locate all well effluents located in the watershed.

Alkalinity

Only eight of the 143 discharges inventoried in the watershed contained alkalinity in excess of acidity. All of these source were strip mine effluents. With the exception of Craggs Run, alkalinity concentrations of all stream sampling points were depleted to zero.

Hardness

A total of nearly 3.1 tons per day of hardness was discharged to streams of the watershed by the sources measured. This value represents approximately one-fourth of the total hardness measured at the mouth of Licking Creek during the 1964 survey.

The highest hardness concentration measured in the watershed was 2,400 mg/l from Mine No. 4334, an abandoned strip mine.

Data on coal mine drainage contributing to hardness in significant amounts are calcium, magnesium, iron, manganese, and aluminum.

Sulfate

Acidic and alkaline mine waters both commonly contain high concentrations of sulfate ions. The source of sulfate in these mine effluents are sulfidic ores and dissimilation of sulfur. The sulfate content of streams resulting from acid mine drainage is indicative of the amount of total acidity that has been discharged to them through mine drainage. This sulfate content is the residual component of neutralized acidity as well as a measure of acidity not yet subjected to neutralization.

A total sulfate loading of 8.6 tons per day was measured in the Licking Creek watershed. The average sulfate loading measured at the mouth of Licking Creek during 1966 was 11.3 tons per day (Table 12).

The highest sulfate concentration encountered during the study was 7,250 mg/l from Mine No. 4572, an abandoned strip mine.

Total Iron

A total iron load of 673 lb/day was discharged to Licking Creek and its tributaries by the 143 discharging sources. The average iron loading measured at the mouth of Licking Creek during 1966 was 1,039 lb/day while the minimum and maximum values measured were 355 lb/day and 1,794 lb/day, respectively.

With the exception of Craggs Run (Station No. 4595) and Cherry Run (Station No. 4592) iron loadings are excessive for all stream sampling locations shown in Table 12.

Manganese

Similar to the occurrence of other mine drainage related parameters, manganese concentrations were high at all stream sampling locations shown in Table 12. A total of 283 lb/day of manganese was measured at the mining sites.

Table 14 presents a summary of flow volume and chemical loadings, by type of source, for the 143 discharging sources inventoried.

At the time of the survey there were several active strip mines and one small underground mine. There were no discharges from the active strip mines. An acid load of only 27 lb/day was measured at the active underground mine (Mine No. 4626).

Both active, abandoned strip mines, and active mines were the principal sources of acid pollution in the Licking Creek watershed. The mines all contained iron structures or abandoned operations and comprise about 87 percent of the total acidity measured in the watershed. However, there were additional major sources of acid pollution not associated in the above categories.

CONCLUSIONS

From the preceding discussion it is apparent that particular

Table 16

Mass drainage loadings
leaching fresh water area

Stream Name	No.	Area (Acres)	Total Sulfate (lb/day)	Total Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Swift Run (subsurface)	10	125	1,372	1,466	106	54
Contribution Swift Run ^{1/2} (subsurface)	10	250	1,212	2,245	191	44
Swift Run ^{1/2} (subsurface)	100	600	2,446	5,668	178	162
Contribution Swift Run ^{1/2} (subsurface)	0	60	120	661	20	7
Big Spring (subsurface)	0	10	600	186	176	14
Swift Run (surface)	1	6	77	163	2	2

total	100	1,000	8,216	10,110	673	283
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^{1/2} Surface and underground areas containing within the same area, with the principal portion of the discharge coming from the underground area.

^{2/2} Surface and underground areas containing within the same area, with the principal portion of the discharge coming from the surface area.

pollution abatement emphasis will have to be placed upon abandoned drift mines, combination drift mines, and strip mines. Since nearly 87 percent of the total watershed acidity emanates from these sources, abatement within these source categories would effect significant water quality improvement in the Little Creek watershed.

A more practical method to drainage abatement within the Little Creek watershed involves the principal source approach. Even though the above mentioned source categories constitute nearly 87 percent of the total acid load, these sources total 118. Abatement of all 118 sources is obviously impractical from the standpoint of economics as well as the physical limitations imposed by such an undertaking. The recommended principal source approach to drainage abatement selects drainage sites with respect to the magnitude of their acid loads and the relative contribution of each source to the total watershed problem. Thus, a reduced number of sources are selected for abatement and the expected abatement efficiency level enables estimates to be made of water quality improvement in the receiving streams.

For the preliminary pollution abatement program in Little Creek, 16 sources have been selected. These 16 sources account for 77 percent of the acid load measured in the watershed. This approach requires abatement of only a comparatively few sources and includes all significant sources of acid pollution irrespective of source type.

In order to realize the greatest effect resulting from this drainage pollution control, it is necessary to select a suitable chemical parameter on which calculations are to be based. Since Little Creek is a consistently acid stream and no substantial acid sources are known in the basin, and sulfur is usually considered the single most harmful property of acid mine drainage, total stream acidity is used in this discussion to provide more positive improvement. Sulfur reduction is used also drainage procedures (barriers, sealing, backfilling, etc.) are expected to be correlated with acidity reduction.

MINERAL SOURCES

Mineral sites are identified as potential secondary pollution sources. These sources consist of all strip mines, low grade mines, low combination drift mines, and low gas wells. All of the 16 drainage sources appeared as potential sites.

In the Little Creek watershed 118 sites which contributed an acid load in excess of 100 barrels are considered as potential sources.

The combined acid load of the potential sources was 1,015 barrels (Table 10), about 75 percent of the total measured acidity.

Table 15
Principal mine drainage sources
Licking Creek watershed

Mine No.	Source Type	Flow (gpm)	Specific Conductance	Acidity mg/l	Acidity (lb/day)	Receiving Stream
1227	Strip Mine	40	2,750	410	196	Cherry Run
4314	Strip Mine	4	6,000	5,070	243	Unnamed trib. to Cherry Run
4316	Combination	3	5,500	3,125	112	Craggs Run
4317	Drift Mine	15	5,000	1,930	347	Licking Creek
4412	Combination	6	3,000	1,715	123	Unnamed trib. to Cherry Run
4476	Combination	85	1,950	365	372	Unnamed trib. to Cherry Run
4477	Combination	85	2,100	440	448	Unnamed trib. to Cherry Run
4485	Strip Mine	25	3,600	1,425	427	Little Licking Creek
4491	Gas Well	12	6,500	4,635	667	Little Licking Creek
4564	Strip Mine	8	3,800	1,610	154	Anderson Run
4566	Drift Mine	35	1,900	470	197	Unnamed trib. to Mineral Run
4567	Drift Mine	30	2,800	970	349	Mineral Run
4568	Drift Mine	15	3,000	1,295	233	Mineral Run
4570	Drift Mine	22	1,600	445	117	Mineral Run
4572	Strip Mine	5	6,000	3,320	199	Mineral Run
4599	Strip Mine	8	6,000	2,525	242	Anderson Run
TOTALS	16	398			4,426	

1/ Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the underground mine.

2/ Specific conductance measured as micromhos/cm.

In view of the present technical unknowns involved in the abatement of mine drainage, present methods cannot always be expected to reach a maximum degree of effectiveness. There are at least four of the principal sources which include both surface and underground operations in combination (Mine No.'s 4316, 4412, 4476, 4477). A 75 percent reduction in acid loads for these four sources and the five drift mines (Mine No.'s 4317, 4566, 4567, 4568, 4570) might be a reasonable expectation.

Provided there are no interconnections with underground mines, abatement of strip mine No.'s 1227, 4314, 4485, 4564, 4572, and 4599 should be expected to reach a near maximum degree of effectiveness. For abatement purposes, a 90 percent reduction in acid load is assumed at the strip mine sites. Additionally, small seepage areas located elsewhere within the strip mined area should be significantly reduced coincident with abatement of the major source site.

Abatement of the gas well site (No. 4491) is assumed to attain a maximum degree (100 percent) of efficiency. The well may only require plugging or capping of the existing well casing or it may require the installation of new casing before sealing.

Assuming the respective reductions in acidity loadings from the above source categories, 3,700 lb/day of acidity would be removed from the receiving streams of the watershed.

Abatement of the principal sources outlined in this document are not likely to restore acceptable water quality throughout the entire Licking Creek drainage area. However, as previously stated there is insufficient water quality data available to accurately predict the total effect of source abatement. A recommendation relative to the development of this necessary data is given on page 3. If future data development, or economic or technical constraints prove the infeasibility of the principal source abatement approach, as outlined, it may be necessary to add or delete sources due to the development of more valid correlations between stream water quality and mine discharge characteristics. Perhaps as many as one-half of all the mine drainage pollution sources must be effectively abated in order to obtain acceptable water quality in Licking Creek. Until such a time the principal source approach can effectively serve as the first phase or priority in an action program of drainage source abatement.

The following is a more detailed description of the 16 principal sources recommended in this document for mine drainage abatement. The locations of the principal source sites are shown on Figure 10.

Mine No. 1227

A 40 gpm effluent from Mine No. 1227 carried an acid load of 196 lb/day. The mine is located near the mouth of Cherry Run and results from a stripped out underground mine. There were actually two effluents discharging from the base of the strip mine spoils at this location. The two discharges merged below their point of origin, were piped under the county road and then into Cherry Run.

Mine No.'s 4314, 4316, and 4317

An underground and surface mined area, north of Curllsville contributed an acid load of 702 lb/day to Craggs Run and Licking Creek. It appears that at least two coal seams have been strip mined and numerous underground headings have been driven into the hillside. Eleven mine drainage sources, with discharges totalling 810 lb/day, were sampled in this mining complex. Mine No.'s 4314, 4316, and 4317 with acid loads of 243 lb/day, 112 lb/day, and 347 lb/day respectively, contributed 86 percent of this total acid load. Only minimal reclamation had been instituted at this site. The three discharge points indicate old portal locations or points of intersection of the underground and surface mining operations.

Mine No. 4412

A drift mine opening located in the strip mine highwall of an unreclaimed area strip mine discharged an acid load of 123 lb/day to an unnamed tributary of Cherry Run. Seepage areas along the base of the surface mine spoil piles also contributed an additional but undetermined amount of acidity to the Cherry Run tributary.

Mine No. 4476

This principal source of mine drainage is located just south of the community of Huey. In this area strip, approximately one mile in length, a small unnamed tributary to Cherry Run flows through the unreclaimed strip mine. In addition to spoil pile seepage areas there was also drainage to this small tributary from deep mine openings destroyed during the surface operation. The sample was collected at a point below the disturbed area. The 85 gpm flow carried an acid load of 372 lb/day.

Mine No. 4477

This principal mine drainage source is located approximately 0.2

mile north of Mine No. 4476 in the same area strip operation. Seepage from both surface and underground operations was impounded in the strip cut. An overflow from the impoundment of 85 gpm was sampled. The acid load was 448 lb/day.

Mine No. 4485

Southeast of Sligo, a recent but yet unreclaimed strip mine (at the time of survey) discharged an acid load of 427 lb/day to Little Licking Creek. It is not known whether this strip operation destroyed any old underground mines, however, this general area has been undermined.

No. 4491 (Gas Well)

An abandoned discharging gas well in the community of Sligo contributed an acid load of 667 lb/day to Little Licking Creek. This is the largest single source of acid pollution inventoried in the Licking Creek watershed.

Mine No. 4564

A strip pond located in the final cut of an unreclaimed strip operation contributed an acid load of 154 lb/day to the headwater area of Anderson Run. The overflow from the strip pond was piped under a haulage road and into Anderson Run.

Mine No. 4566

At the headwaters of an unnamed tributary to Mineral Run, a pipe at the base of a slumped drift opening discharged 35 gpm. The pipe is located below the road bed indicating that at one time the mine might have entered under the road. The acid load carried by the discharge was 197 lb/day.

Mine No.'s 4567, 4568

Mine numbers 4567 and 4568 are located adjacent to each other near the headwaters of an unnamed tributary to Mineral Run. A 30 gpm discharge from a mine seal of Mine No. 4567 carried an acid load of 349 lb/day. At Mine No. 4568 a drift opening discharged an additional 233 lb/day of acid to the headwater area. The area immediately behind these old drift openings has been strip mined.

Mine No. 4570

A mine seal discharge of 22 gpm, located on Mineral Run, carried an acid load of 117 lb/day to the stream. The area immediately behind

the seal had been area stripped and left unreclaimed. The remains of a second seal are located just south of Mine No. 4570. A second drainage source, contributing a daily acid load of 45 lb/day was sampled at this point.

Mine No. 4572

North of Sligo a 5 gpm discharge carrying an acid load of 199 lb/day seeped from the low point of a reclaimed strip area. This was the last significant amount of mine drainage received by main stem Mineral Run.

Mine No. 4599

Near the mouth of Anderson Run a cumulative discharge of 8 gpm seeped from the bottom edge of a reclaimed strip area. The acid load carried to main stem Anderson Run at this point amounted to 242 lb/day.

MILL CREEK WATERSHED MINE DRAINAGE INVENTORY

SUMMARY AND CONCLUSIONS

1. The Mill Creek watershed, draining 56 square miles of Clarion and Jefferson Counties, Pennsylvania, has had only limited coal mining activity. All the operations in the watershed appear restricted to strip mining.
2. Mill Creek and several of its tributaries are polluted by coal mine drainage. Mill Creek possesses degraded water quality due to mine drainage from the confluence of Little Mill Creek downstream to its mouth, about six miles. The water draining the affected areas are highly mineralized and devoid of normal aquatic life. The most significant acid discharges are restricted to the Clarion County part of the watershed.
3. Some 50 mining and related sites and an estimated 750 acres of strip mined area were investigated during this study. Samples for chemical analysis were collected from 32 drainage sources, 21 of which were discharging at the time of the survey. Discharges from the coal mine sources ranged from one to 95 gallons per minute (gpm) and totalled 136,800 gallons per day. The pH values of the effluents ranged from 2.7 to 7.6 and total acidity concentrations as high as 3,740 milligrams per liter (mg/l) were recorded. All but two of the mine discharges were acidic. The total acidity loading (less alkalinity) discharged to Mill Creek and its tributaries equalled 6,947 lb/day.
4. The two active strip mine operations in the watershed at the time of the survey contributed no acid load. Three abandoned gas wells discharged an acid load of 77 lb/day. Abandoned strip mines contributed 80 percent of the total mine discharges and about 97 percent of the total mine acidity.
5. Four principal mine drainage sources were found to contribute 92 percent of the acidity loading discharged to watershed streams. It is estimated that physical abatement of these principal sources should produce significant water quality improvement in the Mill Creek watershed.

DESCRIPTION OF AREA

The Mill Creek watershed drains a 56 square mile area in east central Clarion and northwestern Jefferson Counties, Pennsylvania. The headwaters arise in Jefferson County and flow generally west through the two counties to its mouth at Clarion River milepoint 35.0. The drainage area is divided about equally between the two counties.

Generally, the topography varies little throughout the watershed with hilltop elevations exceeding 1,700 feet above sea level found throughout the watershed.

Principal tributaries to Mill Creek and their drainage areas are as follows: Douglas Run - 3.1 sq. mi., Jones Run - 3.0 sq. mi., and Little Mill Creek - 13.7 sq. mi. Fisher, Pennsylvania is the only population center located in the watershed and had a 1960 population of 150. Approximately 35 percent of the watershed lies within State Game Land.

The watershed is bounded on the north by the Clarion River and by Piney and Redbank Creeks on its remaining drainage area boundaries.

The Mill Creek watershed has had only limited mining activity. At the time of the source investigation this activity was limited to surface mining. If underground mining has been done in the watershed, the strip mine operations have destroyed or covered these sites.

STREAM WATER QUALITY

Above the confluence of Little Mill Creek, main stem Mill Creek was unaffected by coal mine drainage. Generally, the pH values of tributaries in this part of the watershed ranged from 6.0 to 7.4 with conductivity values ranging from less than 50 to 140. Fish and other forms of aquatic life were observed along this stretch of Mill Creek.

Little Mill Creek, principal tributary to Mill Creek, was affected by coal mine discharges over its entire length. Below the confluence of Little Mill Creek, Mill Creek exhibited an excess of acidity, sulfate, iron and other mine drainage related parameters.

Douglas Run and Jones Run are two additional tributaries to Mill Creek which were seriously affected by coal mine discharges.

Four stream sampling stations were located on Mill Creek during the mine drainage source investigation (Table 16). One sample and flow measurement was obtained at each of these stations. Additionally, information obtained near the mouth of Mill Creek during a 1966 stream survey is included. A summary of all stream data is presented in Table 17.

In conjunction with sampling and flow measurements at selected stream locations, pH and specific conductance determinations were made at a number of additional stream locations in the watershed.

Table 16

Stream water quality sampling stations
Mill Creek watershed

Station Number	Sampling Period	Stream	Location
4446	September 1967	Mill Creek	Near Mouth
4447	September 1967	Mill Creek	Above Little Mill Creek
4448	September 1967	Little Mill Cr.	Near Mouth
4449	September 1967	Douglas Run	Near Mouth
0517	June, August, September 1966	Mill Creek	Near Mouth

Table 17

Stream water quality data
Mill Creek watershed

Station Number	No. of Samples	Flow (gpm)	pH	Specific Conductance	Total Acidity		Total Hardness		Sulfate		Total Iron		Manganese	
					mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day	mg/l	lb/day
4446	1	21,690	4.6	550	64	16,657	168	43,727	235	61,165	3.0	859	7.2	1,874
4447	1	7,439	5.9	110	-6	-536	35	3,124	25	2,231	0.4	36	0.5	45
4448	1	2,295	3.8	1,500	420	11,566	412	11,346	960	26,438	19.0	6	25.6	705
4449	1	1,535	3.5	1,525	615	11,328	256	4,715	920	16,946	58.0	1,069	25.2	464
0517 ^{1/}	6 ^{2/}	5,310	3.1	1,388	280	16,960	337	19,125	385	20,833	10.6	662	26.0	1,587

^{1/} Additional sampling of Station No. 4446, conducted prior to the mine drainage source investigation.

^{2/} Average of 6 samples, 1966.

^{3/} Specific conductance measured as micromhos/cm.

These values and the locations of stream sampling stations are shown in Figure 11.

Station No. 4447

Mill Creek was unaffected by mine drainage above the confluence of Little Mill Creek. Only two small strip mines were located in this part of the watershed, however, they were dry. The stream at this point was characterized by a somewhat low pH of 5.9 and an acidity concentration of 2 mg/l. However, the alkalinity concentration was 8 mg/l which resulted in a net alkalinity of 6 mg/l. Other mine drainage parameters such as sulfate, hardness, and iron were well below acceptable limits for streams draining coal field areas.

Station No. 4448

Little Mill Creek represents one of the two most acid polluted tributaries in the Mill Creek watershed. Near its mouth the stream carried a daily acid load of 5.75 tons per day. The hardness, sulfate, iron, and manganese loads were also excessive.

Station No. 4449

An acid load of 5.65 tons per day was measured at the mouth of Douglas Run. In addition, this tributary discharged a sulfate load approaching 7 tons per day to Mill Creek. The degraded water quality found on Douglas Run was primarily attributable to the highly acid mine effluents found on its principal tributary, Jones Run. At its mouth, Douglas Run had pH and conductivity values of 3.5 and 1,525, respectively.

Station No. s 4446 and 0517

Stream sampling and gaging conducted coincident with the field inventory and information obtained from a prior stream sampling program (1966) show Mill Creek to be a consistently acid stream. Acidity values near the mouth of Mill Creek ranged from 64 mg/l to 465 mg/l while the acid load averaged over 8 tons per day.

BIOLOGY

A biological evaluation of Mill Creek at Station No.'s 4446 and 0517 was made during 1966 to determine the effect of pollution upon normal aquatic fauna. The benthic organisms collected consisted almost entirely of acid tolerant forms. The substrate of the stream was characterized by physical evidence of mine drainage pollution

which included red stains on rocks, sediment characteristics, and lack of biological growths. However, in spite of the biological degradation in the Mill Creek watershed, this pollution criteria is not as severe as that found in the other five Clarion River watersheds studied.

In summary, all but one of the mine drainage-affected stream locations were characterized by acidic pH values below 4.7, specific conductance values exceeding 550 micromhos per centimeter, and alkalinity concentrations which were depleted to zero. Except for the sampling point at the mouth of Little Mill Creek the acidity values of the affected streams ranged from 64 mg/l to 615 mg/l, hardness values from 168 mg/l to 460 mg/l, and sulfate values from 235 mg/l to 960 mg/l. At Station No. 4449, Douglas Run at mouth, iron and manganese concentrations of 58 mg/l and 25.2 mg/l respectively, were recorded.

SOURCES OF MINE DRAINAGE

Some 50 mining and related sites and an estimated 750 acres of strip mined area were investigated during this study. Samples for chemical analysis were collected from 32 drainage sources, 21 of which were discharging at the time of the survey. Discharges from the coal mine sources ranged from one to 95 gpm and totalled 136,800 gallons per day. The pH values of the effluents ranged from 2.7 to 7.6 and total acidity concentrations as high as 3,740 mg/l were recorded. All but two of the mine discharges were acidic. The total acidity loading (less alkalinity) discharged to Mill Creek and its tributaries was 6,947 lb/day.

A detailed description of the mine drainage sources in the Mill Creek watershed follows. All mine sites inventoried in the watershed are shown in Figure 12 following the source description section.

Headwaters

Above the confluence of Little Mill Creek, main stem Mill Creek and its headwater tributaries were unaffected by coal mine discharges. Only two areas of limited mining activity were located in the headwaters area. These were located in the area of Martin and Rankin Runs on the north bank of the main stem, however, both were dry at the time of inspection. A gas well located on the south bank directly across from the above mentioned mines, discharged an alkaline load of 2 lb/day to Mill Creek. This gas well effluent was the only source of discharge located in the headwater portion of the watershed.

Minor tributaries and the main stream in this headwaters area

exhibited pH values ranging from 5.2 to 7.5 and conductivity values ranging from < 50 to 140 micromhos per centimeter. Fish and other forms of aquatic life were found in this portion of the watershed.

Little Mill Creek

Little Mill Creek was one of the two major contributors of mine acidity and related parameter loadings to Mill Creek. The tributary was affected in varying degree by the acid discharges over its entire length.

A gas well effluent, carrying an acid load of 43 lb/day (No. 4368), was the first pollution source to enter the headwaters of Little Mill Creek. Several strip mines in the immediate vicinity were investigated but found dry. North of the community of Corsica, on the south bank of Little Mill Creek, a strip mine was just beginning operation at the time of the survey. This mine was the continuation of an earlier abandoned operation. No discharge points were located at either mine, however a small strip mine pond located in the older working was sampled (No. 4367). Just east of this strip mine a small unnamed tributary has been contour strip mined along both banks. Although partially reclaimed, the water of this tributary was forced to flow around and through the strip mine spoil piles. As a result, an acid load of 74 lb/day was carried by the tributary below the disturbed area. Directly across from this operation, on the north bank of Little Mill Creek, several abandoned strip mines and one active strip mine were investigated. Several strip ponds and small seepage areas at the abandoned sites were sampled, however, the acid loads were negligible. The active operation was dry.

The mining sites discussed in the above section were all located in the Jefferson County portion of the Little Mill Creek watershed. The majority of the operations were dry and do not contribute acid water except during periods of high surface water runoff.

The lower Little Mill Creek drainage area (Clarion County) contained the majority of the mining sites and was primarily responsible for the degraded water quality found in this portion of the watershed.

The first significant amounts of acid water were carried to Little Mill Creek by a small unnamed tributary just east of the Clarion County line on the south bank of the main stem. An unreclaimed hilltop area strip mine is located at the headwaters of this tributary and a contour strip mine runs along the east bank in the lower part of the tributary. The acid load discharged by the headwaters area strip mine, No. 4284, was 4,263 lb/day. A small strip mine pond located south of Interstate 80 and fed by subsurface flow

and intermittent surface runoff was the origin of the discharge. The discharge was piped under the highway and into the unnamed tributary. This acid load was the largest encountered in the watershed and contributed 66 percent of the total watershed acid load. This mine effluent was classified as one of the four principal watershed sources. The contour strip mine located on the east bank (Mine No. 4242) contributed an additional acid load of 317 lb/day to the tributary. The strip mine was abandoned without reclamation and the discharge now emerges from a low point in the spoil piles. The mine was also classified as a principal pollution source.

Douglas Run, Jones Run

Douglas Run was the next downstream tributary to Mill Creek affected by mine drainage. Several strip mines were investigated in the Douglas Run drainage area, however, no major sources of acid pollution were located. The total source acid load was only 53 lb/day. The three discharge points contributing to this total (Mine No.'s 4240, 4248, and 4249) were from seepage areas located at the base of strip mine spoil piles. There were additional seepage areas at these mine sites contributing immeasurable amounts of drainage.

Jones Run, which comprises one-half of the total 6.1 square mile Douglas Run drainage area, was primarily responsible for the degraded water quality in Douglas Run. The upper half of Jones Run contained the major portion of the mining activity located in the Mill Creek watershed. The headwaters of this tributary have been completely stripped out. Six seepage areas around the perimeter of this disturbed area contributed a combined acid load of 284 lb/day to Jones Run. Most of the acid load discharged to Jones Run was carried by two tributaries located within the mined area. Only partial reclamation has been done at the mining site. The tributaries are in contact with acid producing materials exposed during the mining operation. The tributaries were sampled and flow measurements taken immediately below the strip mine operations. The acid loads carried by Station No.'s 4356 and 4357 were 907 lb/day and 892 lb/day, respectively. Both of these sources are classified as principal watershed pollution sources.

At its mouth, Douglas Run had a pH of 3.5 and an acidity concentration of 615 mg/l.

Mill Creek - main stem

Below Douglas Run two sources of unknown origin discharged acid loads to Mill Creek. At Station No. 4360 a highly iron discolored discharge emerging from the stream bed of a small unnamed tributary

carried an acid load of 144 lb/day to Mill Creek. The headwaters of the tributary were clear but near its mouth it suddenly became discolored and the pH dropped to 3.4. Since there was no mining or gas well activity in the area, this suggests a form of natural pollution resulting from coal outcropping in the stream bed. A similar occurrence was found at Station No. 4252, however, the acid load was only 8 lb/day.

Whites Run

Whites Run is the last downstream tributary to Mill Creek which had experienced any mining activity. Two small strip mine operations were located within the Whites Run drainage area, one on each side of the tributary. The uppermost strip mine was dry and a strip pond located in the lower mine was sampled, however, it had no discharge.

DISCUSSION

Acidic mine effluents located on Little Mill Creek and Jones Run (tributary to Douglas Run) were primarily responsible for the degraded water quality found in the Mill Creek watershed. These tributaries were acidic, highly mineralized, and devoid of normal aquatic life. Approximately 20 square miles, or about one-third of the total watershed drainage area, were so affected.

A total of 32 mine drainage sources were identified and sampled for chemical analysis. Twenty-one of these were discharging at the time of inspection. The total measured discharge was 423 gpm, or 0.61 million gallons per day emanating from coal mine sources. About 42 percent of the total discharge volume was received by Little Mill Creek and its tributaries. Another 39 percent of the total discharge volume was received by Jones Run. Table 18 presents an area breakdown of mine drainage in terms of the total flow and total loadings (lb/day) of polluting constituents discharged to receiving streams in the Mill Creek watershed.

Acidity

From Table 18, a total acid load of 3.5 tons per day was discharged by 21 sources at the time of the study. Over 96 percent of this total load, 3.35 tons per day, was discharged from the 13 discharge points on Jones Run and tributaries to Little Mill Creek. A more significant comparison between discharge points and total acid load is realized when only the four principal mine discharges are considered. These four sources contributed almost 92 percent or 3.2 tons per day of the total watershed acid load.

Table 18

Mine drainage loadings
Mill Creek watershed

Receiving Stream	Stream Mile/	Drainage Area (sq.mi.)	No. of Mine Discharges	Total Discharges (gpm)	Total Net Acidity (lb/day)	Total Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Mill Creek	-	-	1	5	-2	3	3	1	0
Unnamed tribs to Mill Creek	-	-	2	65	152	315	519	6	10
Little Mill Creek	5.80	13.7	1	7	43	61	111	2	6
Unnamed tribs to Little Mill Cr.	-	-	5	169	4,656	2,201	6,329	522	109
Jones Run	5.60	3.0	8	165	2,045	946	3,041	78	119
Douglas Run	5.10	6.1	3	8	53	33	69	2	1
Whites Run	0.40	1.8	1	4	0	1	2	0	0
TOTALS			21	423	6,947	3,560	10,074	611	245

L/ Distance above mouth of Mill Creek.

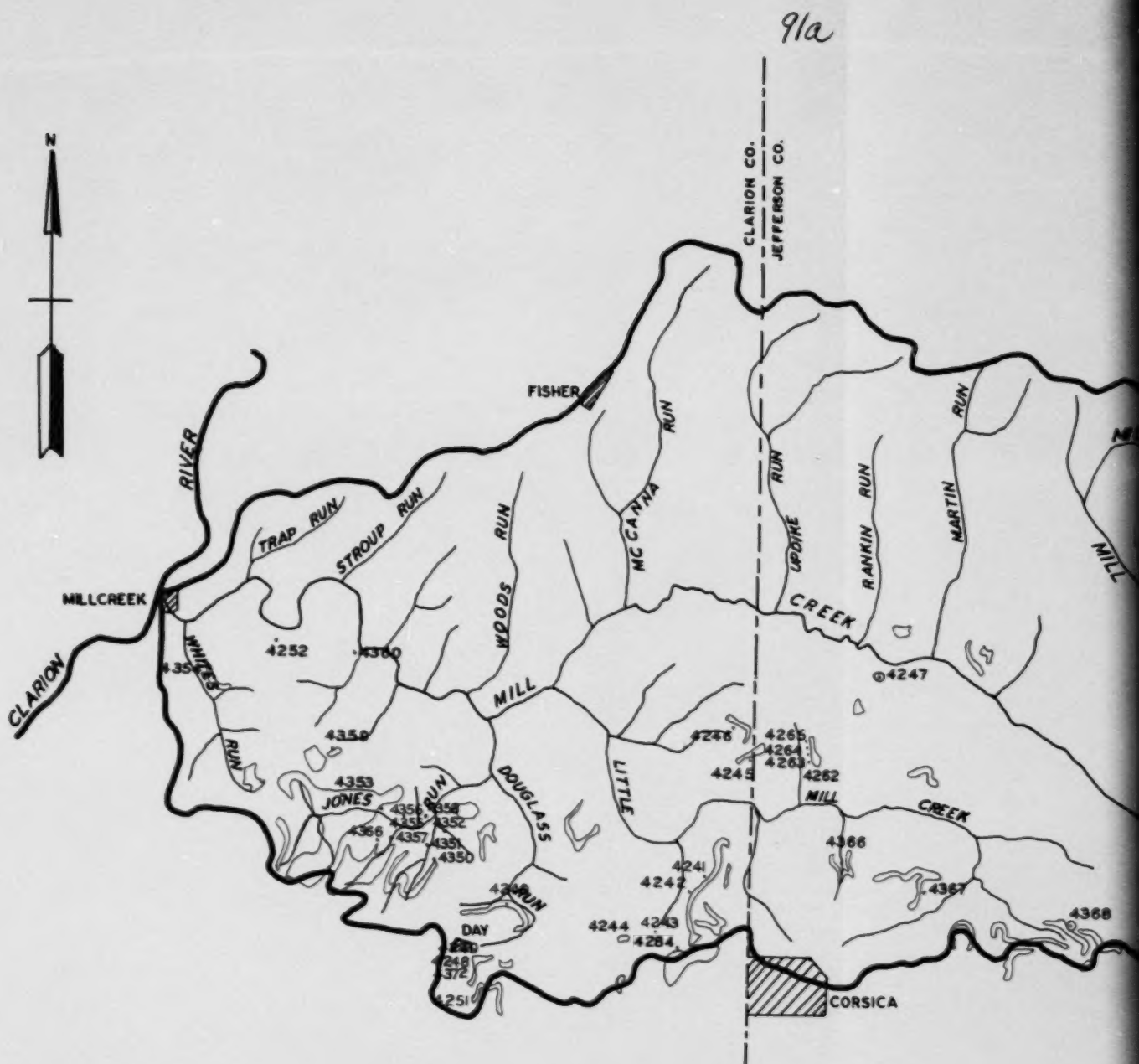
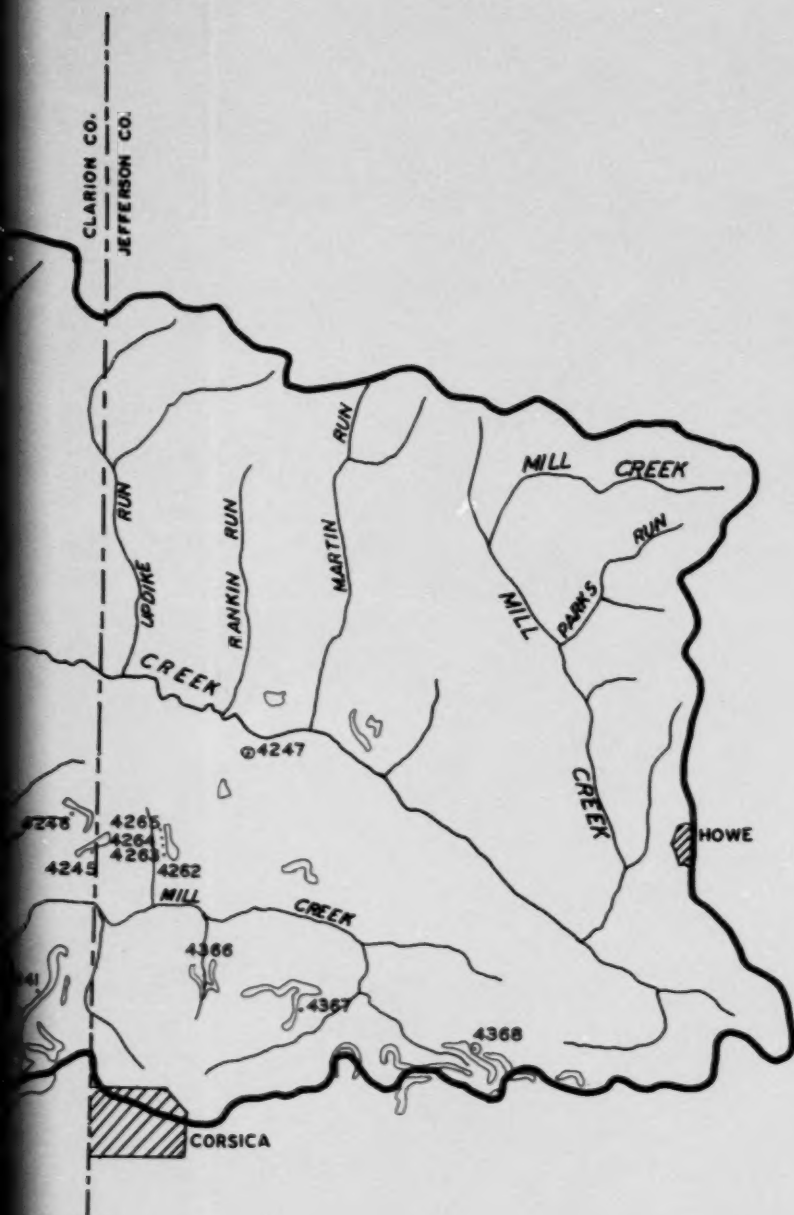


FIGURE 12
MILL CREEK WATERSHED
SOURCES OF MINE DRAINAGE

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- LEGEND—
- ⊗ ABANDONED GAS WELL
 - UNDERGROUND MINE
 - SAMPLING POINT LOCATION
 - ▨ MINE REFUSE
 - 〰 STRIP MINE

FIGURE 12
MILL CREEK WATERSHED
SOURCES OF MINE DRAINAGE POLLUTION

B

An average acidity loading of some 8.5 tons per day (Station No. 0517) was measured in Mill Creek downstream of all mine drainage inflow. This loading was some 5 tons per day more than the total of all the individual sources measured (3.5 tons per day). This difference is attributed to that quantity of drainage over the watershed which was not measurable at point sources and therefore not directly quantifiable. In addition, the varying hydrologic periods under which the stream sampling was conducted exerts a wide variation in the acidity loading measured in the stream. Heavy surface water runoff over the unreclaimed strip mine spoil piles adds additional acidity to the watershed which is not present during periods of normal stream flow. On all but one occasion during the 1966 stream survey, Mill Creek carried an acidity loading which far exceeded the total of the individual sources. The maximum acid load (12.5 tons per day) was measured during the period of maximum flow conditions (17.5 cfs) and the minimum acid load (3.5 tons per day) during the period of lowest flow conditions (5.10 cfs).

Additional sources of acid pollution from abandoned oil and/or gas wells may be responsible for some of the discrepancy between stream loadings and the total of the individual loads. Although the two inventoried gas wells contributed an acid load of only 77 lb/day, no specific attempts were made to document these potential pollution sources for the entire watershed.

Alkalinity

Alkalinity concentrations in the 21 discharging sources located throughout the Mill Creek watershed were extremely low. In all but two samples the alkalinity was depleted to zero. Discharge No. 4247, an abandoned gas well contributed a net alkalinity of 2 lb/day to Mill Creek.

Hardness

A total of 1.78 tons per day of hardness was discharged to the streams of the watershed by the sources measured. This loading comprised only 19 percent of the average total hardness found near the mouth of Mill Creek during the 1966 stream survey. About 88 percent of the mine drainage hardness was discharged to Jones Run and tributaries to Little Mill Creek.

The highest total hardness concentration encountered during the study was 1,700 mg/l from an abandoned strip mine (No. 4284).

Sulfate

Acidic and alkaline mine water commonly contains high concentrations of sulfate ion. The sulfate content of streams draining coal

mining areas is indicative of the amount of total acidity that has been discharged to them through mine drainage. This sulfate content is the residual component of neutralized acidity as well as a component of acidity not yet subjected to neutralization.

Nearly 94 percent of the total sulfate loading in the mine effluents (Table 18) was discharged to Jones Run and tributaries of Little Mill Creek. Approximately 10.5 tons per day of sulfate was measured at the mouth of Mill Creek. This load is approximately twice the total of the individual sulfate loads from coal mine sources. The largest single source of sulfate in the watershed was Mine No. 4284, an abandoned strip mine.

Total Iron

For all but one of the stream locations for which analytical data is shown in Table 17, total iron concentrations and loadings were high. The exception being Mill Creek above the confluence of Little Mill Creek, where the iron concentration was 0.5 mg/l and the daily iron load was 36 lb/day. This reflects the natural water quality found in this area of the watershed as it is not affected by coal mine drainage.

As with the other mine drainage related parameters, Jones Run and tributaries to Little Mill Creek receive most of the iron load,

Manganese

Similar to the occurrence of iron, manganese concentrations were high at all stream sampling locations (Table 17), excepting Mill Creek above the confluence of Little Mill Creek. At this point Mill Creek carried a manganese concentration of 0.5 mg/l, which is generally acceptable for streams draining coal field areas. The highest manganese load encountered during the study period was 84 lb/day from Mine No. 4284.

Table 19 presents a summary of flow volumes and chemical loadings, by type of source, for the 21 discharging sources inventoried.

At the time of the field study there were only two active mining operations in the watershed. Both of these were strip mines and contributed no acid load or discharge.

Inactive or abandoned strip mines were found to be responsible for 80 percent of the total mine drainage discharge in the basin which carried approximately 88 percent of the total coal mine acidity.

Table 19
Mine drainage loading by source type
Mill Creek watershed

Source Type	Number	Total Discharges (gpm)	Total Net Acidity (lb/day)	Total Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Strip Mines (inactive)	15	340	6,704	3,137	9,336	591	226
Gas Wells (inactive)	3	16	77	97	188	12	8
Unknown	2	65	152	315	519	6	10
Spring	1	2	14	11	31	2	1
TOTALS	21	423	6,947	3,560	10,074	611	245

POLLUTION ABATEMENT

From the foregoing discussion it is apparent that particular mine drainage pollution abatement emphasis will have to be placed upon abandoned strip mine sources. A repetitive sampling program should be instituted at the mining sites in order to more clearly determine their pollution effect during varied hydrologic periods. In addition, a more detailed field survey is required at these sites. This survey should include a closer examination of the disturbed area in order to determine if all drainage points were located during the preliminary survey. Also, the possibility of interconnection with underground mine workings should be investigated. This additional survey work is necessary to determine the feasibility of abatement measures at the individual mining sites.

Through the use of their bond issue money the State of Pennsylvania has initiated additional engineering studies in the Mill Creek watershed since the completion of the 1967 survey. Plans are also under development for the sealing of abandoned gas and/or oil wells, the reclamation of strip mines, and the construction of a treatment facility.

In order to predict the water quality effect of an expected efficiency level of drainage source control, it is necessary to select a critical chemical parameter on which calculations may be based. Since Mill Creek is a consistently acid stream, and there are no industrial acid sources in the watershed, and acidity is usually considered the single most devastating property of coal mine drainage, total stream acidity is used in this discussion to predict water quality improvement through source control measures. Similar reductions in other mine drainage parameters (total hardness, sulfate, iron, manganese) are expected to be coincident with acidity reduction.

PRINCIPAL SOURCES

Four mine drainage sources contributed the major portion of the net acid load received by streams in the Mill Creek watershed. These sources are all abandoned strip mines. Their combined acid load was 6,379 lb/day, about 92 percent of the total load. (Table 20)

In the Mill Creek watershed all mine sites which contributed an acid load in excess of 300 lb/day are considered as principal sources.

Assuming that the strip mined areas do not interconnect with underground mine workings, a minimum 90 percent reduction in polluting constituents is a reasonable expectation achievable with strip mine

Table 20

Principal acid mine drainage sources
Mill Creek watershed

Mine No.	Type of Mine	Flow (gpm)	pH	Specific Conductance	$\frac{L}{mg/l}$	Acidity lb/day	Receiving Stream
4242	Strip	30	4.0	2,800	883	317	Unnamed trib to Little Mill Creek
4284	Strip	95	3.2	5,000	3,740	4,263	Unnamed trib to Little Mill Creek
4356	Strip	60	3.4	2,800	1,260	907	Jones Run
4357	Strip	80	3.4	2,000	930	892	Jones Run
TOTAL						6,379	

$\frac{L}{}$ Specific conductance measured as micromhos/cm.

drainage control. Assuming this 90 percent reduction at the four principal drainage sites, nearly three tons per day of acidity would be removed from receiving streams.

Such an acidity reduction at the points of discharge would effect a similar reduction in Mill Creek at its mouth (Station Nos. 4446, 0517-Table 17). However, as the limited amount of data for this station indicates, the acid load carried at the mouth of Mill Creek is subject to wide variation. It is for this reason that a program of repetitive water quality measurements should be undertaken in an attempt to correlate the fluctuation in acid discharges from the principal mine sites with the acid load carried by the receiving streams. If it is found that the high acid load carried by Mill Creek results chiefly from surface water runoff adding additional acidity to the receiving streams, and not from sources other than those located during the initial field study, then a program of source abatement can be instituted at the principal source sites.

The principal source abatement approach outlined in this document (four sources) may prove sufficient to produce acceptable stream water quality in the Mill Creek watershed. If not, the principal source approach can effectively serve as the first phase or priority in a larger program of drainage source abatement.

The following is a more detailed description of the four principal sources recommended in this document for abatement. The locations of the sites are shown in Figure 13.

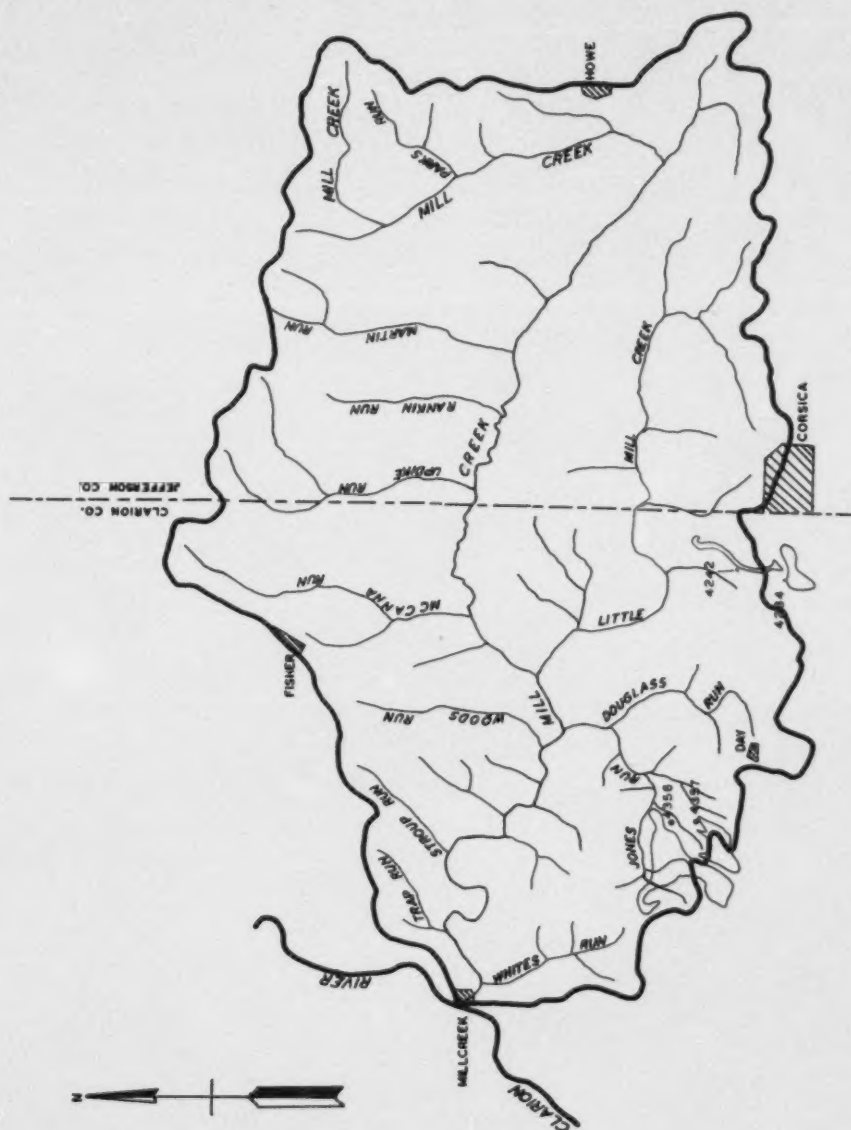
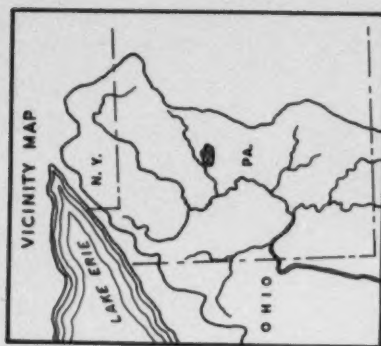
Mine No. 4242

Northwest of the community of Corsica, an unnamed tributary to Little Mill Creek receives a mine discharge of 30 gpm from an unreclaimed strip mine area. The contour strip is located high on the hillside just inside the Mill Creek drainage divide. No evidence of any past deep mining activity was encountered in this area during the survey. The acid load carried to the receiving stream was 317 lb/day.

Mine No. 4284

A hilltop area strip mine located on the drainage divide separating the watersheds of Mill, Piney, and Redbank Creeks contributed an acid load of 4,263 lb/day to an unnamed tributary of Little Mill Creek. Past stripping operations have been active in two coal seams at this location. A small strip mine pond located south of I-80 was the origin of the discharge. The discharge was piped under

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—LEGEND—

- ABANDONED GAS WELL
- ✕ UNDERGROUND MINE
- SAMPLING POINT LOCATION
- MINE REFUSE
- STRIP MINE

FIGURE 13
MILL CREEK WATERSHED
PRINCIPAL MINE DRAINAGE SOURCE LOCATIONS

I-80 via culvert and into the unnamed tributary. This acid load of 4,263 lb/day was the largest encountered in the watershed and contributed 66 percent of the total source acid load measured.

Mine No.'s 4356, 4357

The upper part of two headwater tributaries to Jones Run have been disturbed by strip mining operations. The tributaries draining these strip mined areas were severely degraded, however, no direct discharge points were found during the survey. Only partial reclamation had been done at these sites and the tributaries were in contact with acid producing materials exposed during the mining operation. The tributaries were sampled and flow measurements taken immediately below the strip mined areas. The acid loads carried by Station No.'s 4356 and 4357 amounted to 907 lb/day and 892 lb/day, respectively. The strip mine area influencing these tributaries was the largest single disturbed area in the watershed.

PINEY CREEK WATERSHED MINE DRAINAGE INVENTORY

SUMMARY AND CONCLUSIONS

1. The Piney Creek watershed, draining 70 square miles of Clarion County, Pennsylvania has been severely degraded as a result of coal mine discharges. Both underground and surface mining methods are common in the watershed, however, both types of operations are of only limited size. The Piney Creek watershed has the additional problem of polluted water flowing from abandoned gas wells. However, the acidity contribution from the wells was negligible.
2. The water quality of Piney Creek was only moderately affected in the upper reaches of the watershed. Although significant sources of acid drainage were located at the headwaters of Piney Creek, the downstream effects of mine drainage were diluted by alkaline tributaries entering the main stream. However, below the confluence of Little Piney Creek the main stream was continuously polluted as a result of coal mine drainage.
3. Approximately 100 mining sites and an estimated 1800 acres of strip mined land were investigated during this study. Samples for chemical analysis were collected from 79 sources discharging at the time of the survey. Discharges from the coal mine sources ranged from one to 252 gpm. The total effluent from all sources was 1632 gallons per minute (gpm) or 2.3 million gallons per day (mgd). The pH of the effluents ranged from 2.5 to 7.0 and total acidity concentrations as high as 11,750 mg/l were measured. The total net acid load (less alkalinity) discharged to Piney Creek and its tributaries was 10,941 lb/day.
4. There were three active strip mine operations in the watershed during the study which discharged significant acid loads. The principal sources of acid pollution were abandoned strip mines. The acid load discharged by these sources was 52 percent of the total acidity measured in the watershed.
5. Twenty-four mine drainage sources are identified as principal watershed sources. These sources consist of 14 strip mines (three active), six drift mines, and four combination underground-surface mines. The combined acid load of the principal sources was 9,624 lb/day, about 88 percent of the total measured acidity.

DESCRIPTION OF AREA

Piney Creek rises northwest of Kingsville, Clarion County, Pennsylvania and flows generally westward through Greenville and Reidsburg, some 19

miles to its confluence with the Clarion River at milepoint 21.6. The watershed drains about 70 square miles of east-central Clarion County and less than a quarter of a square mile of Jefferson County.

Topography in the eastern upstream part of the watershed is subdued with wide valleys and gentle hill slopes, but the western part of the watershed has narrow valleys and steep hillsides.

Principal tributaries to Piney Creek and their drainage areas are Brush Run (12.6 sq. mi.), Little Piney Creek (12.5 sq. mi.), Reids Run (6.6 sq. mi.), and Sloan Run (4.6 sq. mi.).

The Piney Creek watershed is bounded on the east and south by tributaries to Redbank Creek, on the west by the Clarion River and its minor tributaries, and on the north by tributaries to Mill Creek.

Mining operations in the Piney Creek watershed are rather evenly distributed about the perimeter of the drainage area. With the exception of the area south of Mechanicsville, extensive mining operations were absent in the interior portions of the watershed.

Strip mining has been the predominant method employed for the mining of coal in the watershed. Most of these operations are hilltop or flatland operations occasionally associated with small underground mines.

STREAM WATER QUALITY

The extreme headwaters of Piney Creek received acid mine drainage from numerous sources which immediately degraded the water quality of the main stream. However, no additional significant mine effluents were discharged to the main stem before the confluence with Little Piney Creek. Due to the neutralization and dilution effects of many small alkaline tributaries, Piney Creek had a pH of 6.7 and a net alkalinity concentration of 5 mg/l above the confluence with Poe Run.

Above the confluence with Little Piney Creek, other tributaries such as Poe Run, Glade Run, Sloan Run, and Parsons Run discharged water that was only moderately affected by mine drainage. The stretch of Piney Creek from Kingsville downstream to the confluence of Little Piney Creek supported some aquatic life. Below the confluence of Little Piney Creek, mainstem Piney Creek was continuously polluted as a result of coal mine discharges. This degraded water quality condition continued along the remaining downstream length of Piney Creek to its confluence with the Clarion River.

The Piney Creek watershed experiences the additional problem of

abandoned gas well effluents. These discharges are chemically similar to the coal mine discharges.

During the field study several stream locations were sampled for chemical analysis (Table 21). These stations were selected to measure the cumulative effects of mine drainage. Additionally, stream sampling data collected near the mouth of Piney Creek during the 1966 stream sampling program is included. A summary of all stream data is presented in Table 22.

In conjunction with sampling and flow measurements of selected stream locations, pH and specific conductance determinations were made at a number of additional stream locations in the watershed. The values and the locations of stream sampling stations are shown in Figure 14.

Station No. 4277

This station was located on Little Piney Creek about midway along its length. The water quality at this point was severely degraded by two highly acid discharges located at the headwaters of the tributary. At the sampling point Little Piney Creek had a pH of 3.2 and carried an acid load of 1,778 lb/day (Table 22).

Station No. 4278

Piney Creek above Poe Run was the only stream sampling site which exhibited an alkaline condition. At this point the stream carried a net alkalinity concentration of 5 mg/l and an alkaline load of 32 lb/day. However, although the stream was alkaline at this point, concentrations of other mine drainage related parameters such as hardness, sulfate, and manganese were quite high. This is due to several mine discharges which are located near the headwaters of the stream. The downstream effects of dilution and neutralization by unpolluted small alkaline tributaries eliminated the acid condition, however, the other associated parameters remained excessive.

Station No. 4279

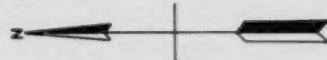
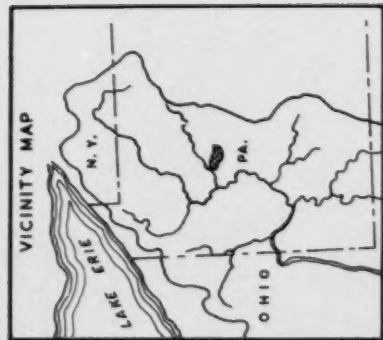
Station No. 4279 was located on Brush Run just north of the community of Mechanicsville. At this point Brush Run had a pH of 3.2 and an acidity concentration of 430 mg/l. In addition to an acid load of nearly 3,000 lb/day, Brush Run carried a sulfate load of nearly 9,000 lb/day. The 28 mg/l iron concentration measured at Station No. 4279 was the highest encountered at any of the stream sampling locations.

Table 21

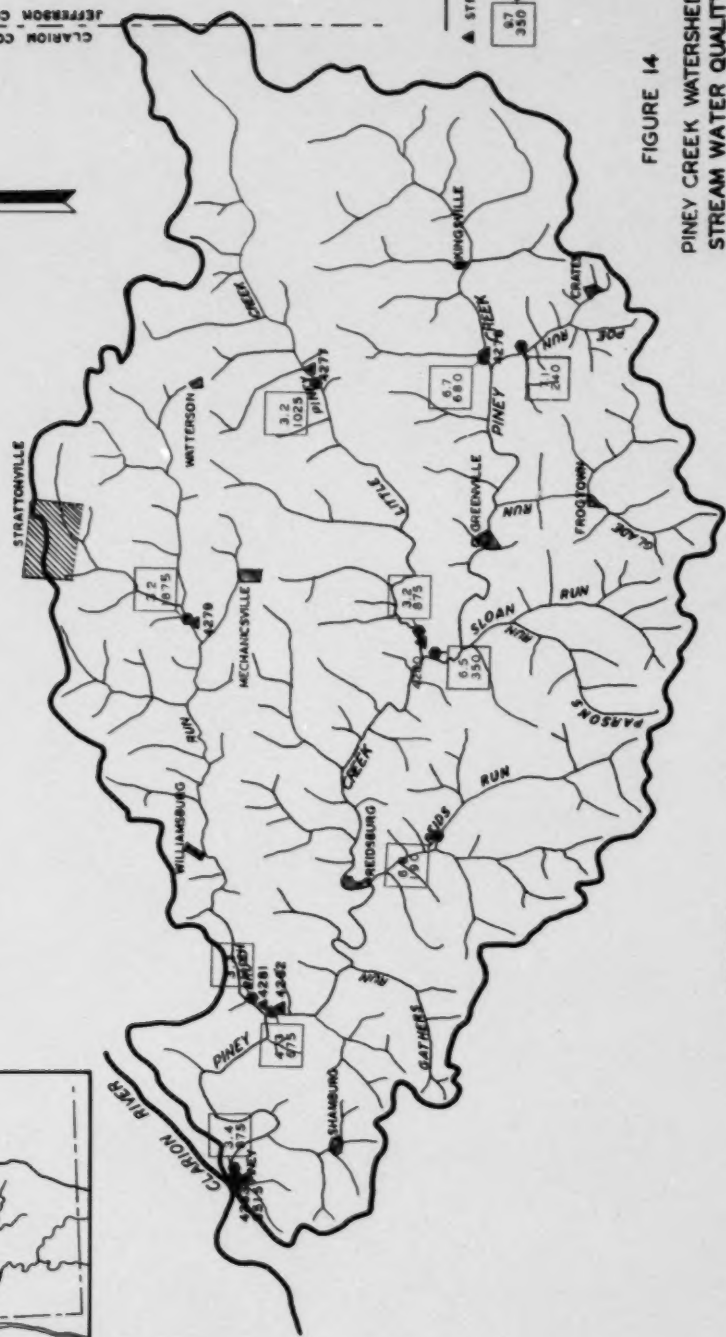
Stream water quality sampling stations,
Piney Creek watershed

<u>Station No.</u>	<u>Sampling Period</u>	<u>Stream</u>	<u>Location</u>
4277	Aug. 1967	Little Piney Creek	At Township road 540 bridge
4278	Aug. 1967	Piney Creek	Above Poe Run
4279	Aug. 1967	Brush Run	At Rt. 66
4280	Aug. 1967	Little Piney Cr.	Near Mouth
4281	Aug. 1967	Brush Run	Near Mouth
4282	Aug. 1967	Piney Creek	Above Brush Run
4283	Aug. 1967	Piney Creek	Near Mouth
0515 ^{1/}	June, Aug., Sept. 1966	Piney Creek	Near Mouth

^{1/} Represents additional sampling of Station No. 4283 conducted prior to the mine drainage source investigation.



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—LEGEND—
▲ STREAM SAMPLING STATIONS
6.7 350
PH
SPECIFIC CONDUCTANCE

FIGURE 14
PINEY CREEK WATERSHED
STREAM WATER QUALITY

SCALE FEET

Table 22
Stream water quality data, Piney Creek watershed Pennsylvania

Station Number	No. of Samples	Flow (gpm)	Specific Conductance ^{3/}	Total Acidity mg/l	Total Acidity lb/day	Total Hardness mg/l	Total Hardness lb/day	Sulfate mg/l	Sulfate lb/day	Total Iron mg/l	Total Iron lb/day	Manganese mg/l	Manganese lb/day
4277	1	549	1,025	270	1,778	178	1,172	500	3,294	13.0	86	14.2	94
4278	1	540	680	-5	-32	296	1,918	310	2,008	1.0	3	10.4	67
4279	1	581	1,875	430	2,997	696	4,852	1,280	8,924	28.0	195	42.4	296
4280	1	1,346	875	15	242	106	1,712	260	4,199	5.0	81	22.8	368
4281	1	1,634	1,300	280	5,490	980	19,215	700	13,725	4.0	71	22.0	431
4282	1	3,690	675	93	4,118	217	9,608	320	14,169	1.0	40	8.8	390
4283	1	6,827	875	20	1,638	216	17,695	470	38,504	3.0	262	13.6	1,114
0515 ^{1/}	6 ^{2/}	10,935	1,008	140	19,272	289	37,806	343	34,255	3.1	568	14.0	2,181

^{1/} Additional sampling of Station No. 4283, conducted prior to the mine drainage source investigation.

^{2/} Average of 6 samples, 1966

^{3/} Specific conductance measured as micromhos/cm.

Station No. 4280

At its mouth Little Piney Creek carried an acid load of only 242 lb/day. This represented a decrease in acid load of some 1500 lb/day from its upstream sampling point at Station No. 4277. The acidity concentration had likewise decreased from 270 mg/l to 15 mg/l, however the pH value remained at 3.2. The sulfate load measured at this point was 4,200 lb/day (Table 22).

Station No. 4281

This station was located near the mouth of Brush Run downstream from all mine drainage inflow. Acid and sulfate loads of 5490 lb/day and 13,725 lb/day, respectively were measured at this point. Other mine drainage related parameters such as hardness and manganese were also high.

Station No. 4282

Piney Creek above Brush Run is representative of nearly the entire drainage area of the watershed exclusive of Brush Run. At this point Piney Creek carried an acid load of 4,118 lb/day. The iron concentration measured at this point was only 1.0 mg/l (40 lb/day) which indicated that the major part of the iron load discharged by coal mine sources within the drainage area was precipitated on the stream bottom.

Station No.'s 4283, 0515

At its mouth Piney Creek carried excessive amounts of all mine drainage related parameters. During the 1965 stream survey, Piney Creek discharged an average acid load of 9.6 tons per day to the Clarion River. The minimum load was only 388 lb/day while the maximum load exceeded 30.5 tons per day. This extreme variation in acid load values is attributable to the widely fluctuating stream flows found during the sampling period. These flow rates ranged from one cubic foot per second (cfs) to a maximum of 90 cfs.

BIOLOGY

A biological evaluation of Piney Creek at Station No.'s 4283 and 0515, Piney Creek near mouth, was conducted during 1966 to determine the effect of pollution conditions upon normal aquatic fauna. The benthic organisms collected consisted almost entirely of acid tolerant forms. The substrate of the stream was characterized by physical evidence of mine drainage pollution which included red stains on rocks,

sediment characteristics, and lack of biological growths.

In summary, all but one of the stream sampling locations were characterized by acidic pH values below 4.4 and specific conductance values above 675 micromhos/cm.

Several of the watershed streams draining coal mining areas were characterized by red appearance and the presence of orange-yellow precipitate in suspension or on the stream bottom. This was particularly evident near the mouth of Piney Creek and along the bank of the Clarion River below the confluence with Piney Creek.

SOURCES OF MINE DRAINAGE

Approximately 100 mining sites and an estimated 1800 acres of strip mined land were investigated during this study. Samples for chemical analysis were collected from 79 sources discharging at the time of the survey. Discharges from coal mine sources ranged from one to 252 gpm. The total effluent from all sources was 1,623 gpm or 2.3 mgd. The pH values of the effluents ranged from 2.5 to 7.0 and total acidity concentrations as high as 11,750 mg/l were measured. The total net acid load (less alkalinity) discharged to Piney Creek and its tributaries was 10,941 lb/day.

A detailed description of the mine drainage sources in the Piney Creek watershed follows. All mine location sites inventoried in the watershed are shown in Figure 15 following the source description section. Mine drainage data is shown in Appendix F.

Headwaters

The headwaters of Piney Creek rise northeast of the community of Kingsville where the water quality of the stream was immediately degraded by a series of abandoned strip mine operations. Parts of the area had been reclaimed, however, there were numerous acid-producing spoil banks remaining from the surface mining operations. The discharges from Mine No.'s 1158, 1159, and 1160 represent cumulative seepage from the base of the strip mine spoil piles. The largest acid load in the entire Piney Creek watershed was found at Mine No. 1173. There were two discharge points located side-by-side which merged immediately below their points of origin. The total measured discharge

was 252 gpm which carried an acid load of 1,542 lb/day. There appeared to be a strong possibility of interconnection with an abandoned underground mine at this site. An underground mine was once located on the back side of the same hill from which the discharges originated. This mine had no discharge at its original opening and considering the 252 gpm flow it is possible that the surface mine operation broke through into the underground workings and created a new drainage course. Mine No. 1173 is identified as a principal mine drainage source in a later section.

Immediately east of Mine No. 1173, an additional source of mine drainage (No. 1165) emanating from the same strip mine complex contributed an acid load of 142 lb/day to an unnamed tributary of Piney Creek. A 15 gpm flow was recorded at Mine No. 1165. The entire discharge resulted from seepage accumulation about the perimeter of the strip mine operation.

There was one active strip mine operation located in the headwater area of Piney Creek. At Mine No. 1157 a 105 gpm pump discharge was measured at the operation. The net acid load was 289 lb/day.

The last inventoried discharge in this headwater area resulted from an abandoned gas well effluent (No. 4263). The discharge contributed an alkaline load of 15 lb/day.

A small tributary to Piney Creek which is located south of Kingsville was affected by mine discharges emanating from an abandoned strip mined area. Five seepage areas resulting from unreclaimed strip mine spoil piles and a water filled strip pit discharged minor acid loads to the unnamed tributary (<5 lb/day). At Mine No. 1180 a 6 gpm effluent was measured from a mine seal. The acid load carried by the discharge was 24 lb/day. Only the mine seal remains to indicate the location of the underground mine as the surface mine operation has destroyed any remaining evidence.

Three abandoned drift mines were also located on a small unnamed tributary to Piney Creek north of Kingsville. Mine No. 1176 was the only mine discharging at inspection and carried an acid load of 13 lb/day.

Poe Run

Four surface mine operations were inspected on the west bank of Poe Run, however no discharges were located. Four strip mine ponds within the strip mined area were sampled. All of the ponds were acid but had no visible effluents.

Glade Run

In the 3.7 square mile drainage area of Glade Run four strip mines and at least six underground mine openings were investigated. Three of the drift mine openings were located within the strip mined area and additional openings may have been destroyed. Mine No.'s 4268 and 4269 discharged acid loads of 37 lb/day and 52 lb/day, respectively. These were the only discharging sources within the Glade Run drainage area at the time of the survey.

Sloan Run

The 4.6 square mile drainage area of Sloan Run is the last downstream tributary to Piney Creek, before the confluence of Little Piney Creek, which was affected by mine drainage. Four strip mines and several underground openings within the strip mined areas were investigated on Sloan Run and its principal tributary, Parsons Run. The only discharging sources were Mine No.'s 4271 and 4272 with acid loads of 25 lb/day and 13 lb/day, respectively.

Little Piney Creek

Little Piney Creek is the principal tributary to Piney Creek and drains an area of 12.5 square miles, approximately 18 percent of the total watershed drainage area. The headwaters of the tributary rise in the northeast corner of the watershed and flow generally southwest to the confluence with Piney Creek.

Extensive surface mine operations located at the headwaters of Little Piney Creek were responsible for the immediate water quality degradation of the tributary. Numerous seepage areas were located around the perimeter of these strip mined areas. Several underground mines once operated in the immediate area, however, these openings have been destroyed or covered by the surface mine operations. Mine No.'s 1161 and 1163 are artesian effluents at the base of the spoil piles and may indicate the approximate location of covered underground mine openings. The acid load carried by Mine No.'s 1161 and 1163 were 554 lb/day and 471 lb/day, respectively. Both mines are identified as principal mine drainage sources.

Below the headwaters area, mining activity was noticeably absent along both banks of Little Piney Creek. Mine No.'s 1139 and 4260 were the only significant sources of mine drainage remaining in the tributary area.

Mine No. 1139 discharged an acid load of 334 lb/day from what appeared to be an old underground mine seal. The seal was still

intact, however, the 30 gpm discharge had broken through to the surface adjacent to the mine seal. The hill behind the seal has been strip mined and possibly interconnects with the underground mine voids.

Mine No. 4260 is located just south of Mechanicsville on an unnamed tributary to Little Piney Creek. There were two openings to the drift mine, only one of which was discharging. The flow was 16 gpm and it carried an acid load of 73 lb/day to the unnamed tributary.

Piney Creek-Main stem

Below the confluence of Little Piney Creek with the main stem and the downstream community of Reidsburg, several abandoned strip mine operations were located. Mine No. 4217 was the only mine which discharged a significant acid load. North of Reidsburg a small strip mined area discharged an acid load of 85 lb/day. A local resident stated that an underground spring was buried by the strip mine spoil piles and was responsible for the 21 gpm effluent (No. 4217).

On the north bank of Piney Creek, between Reidsburg and the mouth of Brush Run, five strip mine ponds and one abandoned drift mine were sampled. All of the ponds were acid but had no visible effluents. Mine No. 4219, located west of Reidsburg, is a sealed drift mine which discharged an acid load of 503 lb/day to Piney Creek. A second seal is located adjacent to No. 4219 but was dry. The discharging seal is identified as a principal watershed source.

The south bank of Piney Creek between Reidsburg and the Clarion River received only moderate amounts of mine drainage. Seven acid strip mine ponds with acidity concentrations ranging from 80 mg/l to 6,655 mg/l were sampled in this part of the watershed. The only sources discharging at inspection were Mine No.'s 4229 and 4233. Mine No. 4229 is a small abandoned drift mine with an acid load of only 8 lb/day. Mine No. 4233 is an unreclaimed circular hilltop strip mine. The 10 gpm effluent resulted from seepage accumulation at the base of the strip mine spoil piles. The acid load discharged to an unnamed tributary of Piney Creek was 186 lb/day.

Brush Run

The Brush Run tributary watershed is the most severely acid polluted part of the Piney Creek watershed. A total of 37 discharging sources were located within this 12.6 square mile area. Approximately one-half of the total source acid load measured in the entire Piney Creek watershed emanated from coal mine sources located on Brush Run.

The first major source of mine acid discharged to the headwaters of Brush Run resulted from strip Mine No. 1141. At this point a 30 gpm effluent carried an acid load of 426 lb/day to a headwater tributary. Between Mine No. 1141 and the mouth of Brush Run there were 13 additional significant sources of acid mine drainage. Each of these sources discharged a minimum of 106 lb/day of acidity to Brush Run and its tributaries. These sources are all classified as principal watershed sources and are identified in a later section of this document.

Piney Creek-main stem

Below the confluence of Brush Run and the confluence with the Clarion River, the north bank of Piney Creek received drainage from three additional coal mine sources and one abandoned gas well.

The gas well (No. 4238) was located on Piney Creek just below the confluence of Brush Run. An acid load of 66 lb/day was discharged by the gas well.

At the time of the source inventory an active hilltop area strip mine overlooking the Clarion River discharged two significant acid loads to Piney Creek. The acid loads discharged by Mine No.'s 4207 and 4208 were 141 lb/day and 858 lb/day, respectively.

The last contributing source of acidity to Piney Creek resulted from an abandoned coal washery. Seepage from a sludge pond carried an acid load of 19 lb/day to Piney Creek.

DISCUSSION

Piney Creek and many of its tributaries are seriously polluted by coal mine drainage. These streams are acidic, highly mineralized, and devoid of normal aquatic life. Main stem Piney Creek was degraded in the headwater area but recovered to some extent due to the effects of neutralization and dilution from downstream alkaline tributaries. From Kingsville to the confluence with Little Piney Creek, Piney Creek was only moderately affected by coal mine drainage and supported some aquatic life. Below the confluence of Little Piney Creek, the water quality of the main stem was seriously degraded.

Table 23 presents an area breakdown of mine drainage in terms of the total flow and total loadings (lb/day) of pollutants discharged to the receiving streams in the Piney Creek watershed.

Acidity

From Table 23, a total acid load of 5.5 tons per day was discharged from the 79 sources draining at the time of the study. The major part

Table 23

Mine drainage loadings
Piney Creek watershed, Pennsylvania

Receiving Stream	Stream Mile $\frac{1}{2}$	Drainage Area (sq.mi.)	No. of Mine Discharges	Total Discharges (gpm)	Total Net Acidity (lb/day)	Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Piney Creek	-	-	7	161	1498	2178	4119	50	90
Tribs to Piney Creek	-	-	16	361	2603	2757	6401	121	226
Brush Run	3.80	12.6	17	216	1579	1950	3923	60	141
Tribs to Brush Run	-	-	20	679	3564	5956	9510	309	339
Little Piney Creek	10.60	12.5	2	79	1025	1015	2373	107	92
Tribs to Little Piney Creek	-	-	11	114	542	709	1249	28	48
Tribs to Poe Run	-	-	1	2	0	5	4	0	0
Glade Run	13.30	3.7	2	3	89	80	191	2	4
Sloan Run	11.20	4.6	1	6	25	48	86	1	3
Tribs to Sloan Run	-	-	1	1	3	2	8	0	0
Parsons Run	11.90	1.6	1	1	13	17	30	0	1
TOTALS			79	1,623	10,941	14,717	27,894	678	944

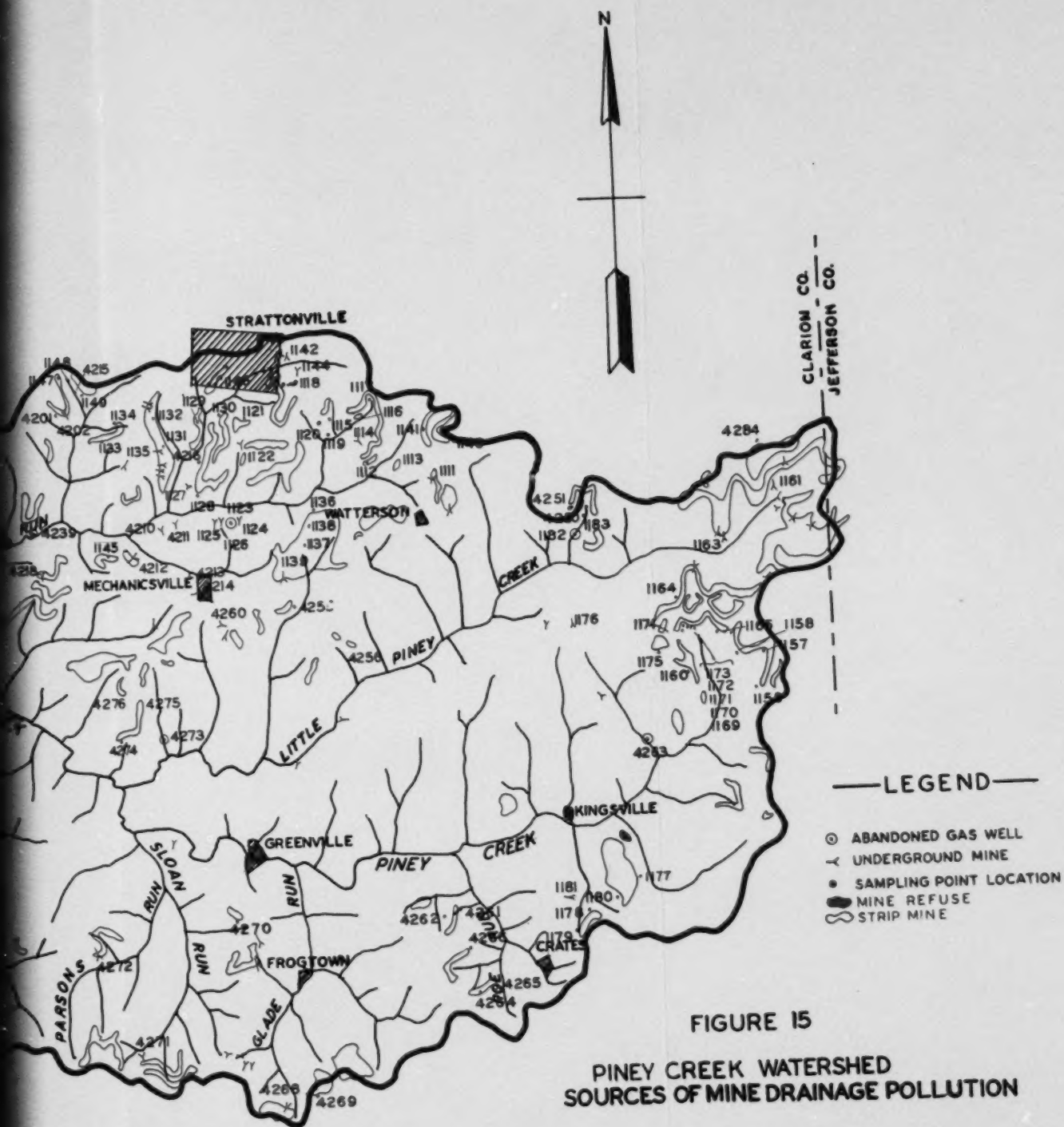
$\frac{1}{2}$ Distance above mouth of Piney Creek.



A



110 a



B

of the mine acidity was discharged to main stem Piney Creek, Brush Run, and their respective tributaries.

An average acid load of some 9.5 tons per day was measured in Piney Creek downstream of all mine drainage inflow during the 1966 stream sampling program (Table 22). This average loading is almost double the sum of the individual discharging mine sites (Table 23). This difference in acid loads does not necessarily reflect failure to locate and sample all sources of watershed acidity, rather it demonstrates the impracticality of making valid correlations between stream loads and the summation of individual discharging mine sites with only limited amounts of the required data. During the 1966 stream sampling program the acid load measured at the mouth of Deer Creek ranged from a minimum of only 388 lb/day to a maximum of over 30.5 tons per day.

This wide variance in acid load values found in the Piney Creek watershed is attributable mainly to periods of differing hydrologic conditions and small increments of mine acidity not directly measurable and therefore not specifically documented in the field inventory. It is particularly difficult to obtain accurate load values from strip mine areas during periods of high flow conditions. Spoil piles at the mining sites, also store water and discharge at widely varying rates.

Alkalinity

Of the 79 sources inventoried only two were alkaline. These two sources were Mine No. 4203, and No. 4263, a gas well. Main stem Piney Creek, just above its confluence with Poe Run (Station No. 4278) was the only stream sampled which was alkaline.

Hardness

The total hardness discharged to watershed streams by coal mine drainage was 7.4 tons per day. Brush Run, the most severely polluted stream in the watershed, received 3.9 tons per day or approximately 53 percent of the total hardness. The hardness values of the discharges ranged from 20 mg/l to 4,600 mg/l. The highest hardness load encountered during the survey was 2,160 lb/day, emanating from Mine No. 4216.

Sulfate

Mine water, either alkaline or acidic, commonly contains high concentrations of sulfate ion. The sources of sulfate in these mine effluents are sulfuric acid and sulfate salts. The sulfate load carried by the receiving streams in coal mining areas is indicative of the total amount of acidity discharged by coal mine sources. This

sulfate content is the residual component of neutralized acidity as well as a component of acidity not yet subjected to neutralization.

The sulfate load emanating from coal mine sources totalled 14 tons per day. Strip mines were responsible for 7 tons per day or approximately 50 percent of the total measured load. The largest single contributor in the watershed was Mine No. 1173, a strip mine, which discharged a sulfate load of 4, 158 lb/day to an unnamed tributary of Piney Creek.

Iron

The total iron load discharged from the 79 sources within the watershed was 678 lb/day. Brush Run and its tributaries received 369 lb/day or 55 percent of the total iron load. The highest iron concentration encountered during the study was 1,100 mg/l (Mine No. 4207). The largest single iron load was 156 lb/day from Mine No. 4216, an abandoned strip mine.

Manganese

Manganese concentrations were unusually high at all stream locations sampled. In all places the manganese concentrations exceeded the iron concentrations. The total load discharged from coal mine sources was 944 lb/day.

The highest manganese load encountered in the watershed was 154 lb/day from Mine No. 1173, an abandoned strip mine.

Table 24 presents a summary of flow volumes and chemical loadings, by source type, for the 79 discharging mines.

At the time of the field investigation there were three active strip mines. These active strip mine operations were all considered principal sources and are discussed in that section. Of the 79 sources sampled, five were gas wells. Only one of these gas wells (No. 4238) contributed a significant amount of acid (66 lb/day).

The principal sources of acid pollution were abandoned strip mines. The acid load discharged by these sources was 52 percent of the total acidity measured in the watershed. However, not all significant sources of mine drainage pollution are restricted to strip mines.

The 35 strip mines listed in Table 24 contributed the following percentages of each parameter: flow, 49 percent; acidity, 52 percent;

Table 24

Mine drainage loadings
Piney Creek watershed

Source Type	No.	Total Discharges (gpm)	Total Net Acidity (lb/day)	Total Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Strip Mines (abandoned)	35	791	5,469	7,569	14,607	306	541
Drift Mines (abandoned)	22	273	1,843	1,461	3,470	163	108
^{1/} Combination Drift Mines (abandoned)	9	334	2,176	3,405	5,578	146	208
Gas Wells (abandoned)	5	97	59	307	424	17	7
^{2/} Combination Strip Mines (abandoned)	4	9	94	97	224	2	7
Strip Mines (active)	3	118	1,281	1,872	3,563	41	73
Coal Washery (abandoned)	1	1	19	6	28	3	0
TOTALS	79	1,623	10,941	14,717	27,894	678	944

^{1/} Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the underground mine.

^{2/} Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the surface mine.

hardness, 52 percent; sulfate, 53 percent; iron, 45 percent; and manganese, 58 percent.

POLLUTION ABATEMENT

From the preceding discussion it is apparent that particular pollution abatement emphasis will have to be placed upon abandoned strip mines. Since more than 50 percent of the total watershed acidity emanated from these sources, abatement within this source category would effect significant water quality improvement in the Piney Creek watershed.

Although strip mine sources within the watershed contributed more than 50 percent of the measured acid load, these sources total 35 (Table 24) and do not include significant discharge points of a different source type. The recommended principal source approach to pollution abatement selects drainage sites with respect to the magnitude of their acid loads and the relative contribution of each source to the total watershed problem. Thus, a reduced number of sources are selected for abatement and the expected abatement efficiency level remains adequate to insure water quality improvement in the receiving streams.

For the preliminary pollution abatement program on Piney Creek, 24 sources have been selected. These sources account for 88 percent of the total acid load in the watershed. This approach requires abatement of 11 fewer sources and includes all significant sources of acid pollution irrespective of source type.

Abatement by source type would be equally successful in removing acidity from the streams of the watershed, however, due to the exclusion of significant acid discharges of a different source type, several areas of water quality concern would remain in the watershed.

In order to predict the water quality improvement resulting from mine drainage pollution control, it is necessary to select a critical chemical parameter on which calculations may be based. Since Piney Creek is a consistently acid stream and no industrial acid sources are known in the watershed, and acidity is usually considered the single most harmful property of coal mine drainage, total stream acidity is used in this discussion to predict water quality improvement. Similar reductions in other mine drainage parameters (hardness, sulfate, iron, manganese) are expected to be coincident with acidity reduction.

PRINCIPAL SOURCES

Twenty four mine drainage sources are identified as principal watershed sources. These sources consist of 14 strip mines (three active), six drift mines, and four combination underground-surface mines.

In the Piney Creek watershed all mine sites which contributed an acid load in excess of 100 lb/day are considered principal sources.

The combined acid load of the principal sources was 9,624 lb/day (Table 25), about 88 percent of the total measured acidity.

In view of the present technical unknowns involved in the abatement of mine drainage, present methods cannot always be expected to reach a maximum degree of effectiveness. There are at least four of the principal sources which include both surface and underground operations in combination (Mine No.'s 1129, 1161, 1163, 4218). A 75 percent reduction in acid loads for these four sources and the six drift mines sites may represent the maximum degree of effectiveness achievable through current abatement techniques.

Provided there are no interconnections with underground mines, abatement of the principal strip mine sites could be expected to reach a near maximum degree of effectiveness. Present strip mine reclamation practices and procedures are sufficient to such a degree that a 90 percent reduction in acid loads is not an unreasonable expectation. The total acid load from the 14 principal strip mine sources was 6,123 lb/day. However, this total load figure includes the discharges from three active strip mines (No.'s 1157, 4207, 4208). As with abandoned mine discharges, the acid loads contributed by these three active sources was representative only at the time of inspection. In this case the acid load from these three strip mine sources (1,281 lb/day) may be substantially reduced upon completion and reclamation of the active areas.

Assuming the respective reductions in acid load from the above source categories, over 4 tons of acidity (8,135 lb/day) would be removed from the receiving streams of the watershed.

The principal source abatement approach outlined in this document (24 sources) may prove adequate to significantly improve the water quality in the Piney Creek watershed. However, as previously stated there is insufficient water quality data available to accurately predict the cumulative effect of source abatement. A recommendation relative to the development of this necessary data is given on page 3. If future data development and economic or technical constraints prove the infeasibility of the principal source abatement approach, as outlined, it may be necessary to add or delete sources due to the development of more valid correlations between stream water quality and

Table 25

Principal acid mine drainage sources
Piney Creek watershed

Mine No.	Type of Mine	Flow (gpm)	pH	Specific Conductance	Acidity (mg/l)	Acidity (lb/day)	Receiving Stream
1115	Strip mine	15	3.0	1,800	590	106	Brush Run
1116	Strip mine	15	3.0	2,800	800	144	Unnamed trib. to Brush Run
1121	Strip mine	60	3.3	3,000	820	590	Brush Run
1125	Drift mine	18	3.0	2,300	695	150	Brush Run
1129	Combination Drift mine	200	3.0	1,950	355	852	Unnamed trib. to Brush Run
1130	Strip mine	60	3.8	2,250	925	666	Unnamed trib. to Brush Run
1136	Strip mine	18	3.6	2,800	735	158	Brush Run
1139	Drift mine	30	3.7	2,500	930	334	Unnamed trib. to Little Piney
1141	Strip mine	30	4.3	4,000	1,185	426	Brush Run
1143	Drift mine	15	3.6	1,900	750	135	Unnamed trib. to Brush Run
1144	Drift mine	30	3.7	1,350	485	174	Unnamed trib. to Brush Run
1149	Strip mine	30	3.5	1,300	350	126	Unnamed trib. to Brush Run
1157	Active strip mine	105	6.3	1,600	224	282	Piney Creek
1161	Combination Drift mine	60	5.6	2,750	770	554	Little Piney Creek
1163	Combination Drift mine	19	3.0	5,000	2,070	471	Little Piney Creek
1165	Strip mine	15	3.3	2,400	790	142	Unnamed trib. to Piney Cr.
1173	Strip mine	252	2.9	2,150	510	1,542	Unnamed trib. to Piney Creek
4207	Active strip mine	1	3.1	8,000	11,750	141	Piney Creek
4208	Active strip mine	12	3.2	8,000	5,965	858	Piney Creek
4214	Drift mine	60	3.8	1,600	305	219	Unnamed trib. to Brush Run
4216	Strip mine	180	4.5	1,800	350	756	Unnamed trib. to Brush Run
4218	Combination drift mine	30	6.5	2,400	305	109	Unnamed trib. to Brush Run
4219	Drift mine	15	3.0	4,500	2,795	503	Unnamed trib. to Piney Creek
4233	Strip mine	10	3.1	4,000	1,550	186	Unnamed trib. to Piney Creek

1/ Surface and underground mines occurring within the same mined area, with the principal portion of the discharge coming from the underground mine.

2/ Specific conductance measured as micromhos/cm.

mine discharge characteristics. Until such time the principal source approach can effectively serve as a first phase or priority in a program of drainage source abatement.

The following is a more detailed description of the 24 principal sources recommended in this document for mine drainage abatement. The locations of the principal source sites are shown in Figure 16.

Mine No. 1115

A small unreclaimed strip mine operation, located southeast of Strattonville, Pa. discharged an acid load of 106 lb/day to an unnamed headwater tributary of Brush Run.

Mine No. 1116

Approximately 0.5 mile east of Mine No. 1115, the east fork of the above mentioned unnamed headwater tributary was seriously affected by drainage emanating from an unreclaimed strip mine. No discharge points were located within the strip mined area, however, numerous immeasurable seepage areas were found along the base of the disturbed area. The acid load carried by the receiving tributary was 144 lb/day.

Mine No. 1121

A partially reclaimed strip mine in the Strattonville area discharged an acid load of 590 lb/day to an unnamed tributary of Brush Run. The 60 gpm discharge flowed through the final cut in the mining operation and was characterized by its intense discoloration.

Mine No. 1125

Approximately 1 mile northeast of Mechanicsville an abandoned drift mine, located on the south side of I-80, discharged 18 gpm to main stem Brush Run. There are two additional mine openings in the immediate area and due to their proximity, interconnection with Mine No. 1125 is possible. The acid load carried by Mine No. 1125 was 150 lb/day. The adjacent openings contributed an additional load of 70 lb/day.

Mine No. 1129

The discharge from Mine No. 1129 is probably the result of a stripped out underground mine. An artesian effluent of 200 gpm flowed from the base of the strip mine and carried an 852 lb/day acid load to an unnamed tributary of Brush Run.

Mine No. 1130

Mine No. 1130 is located just upstream on the same receiving tributary as Mine No. 1129. A pond located within the unreclaimed strip mine area discharged 60 gpm through a low point in the surrounding spoil piles. This mine effluent contributed an acid load of 666 lb/day to the Brush Run tributary.

Mine No. 1136

East of the community of Waterson an 18 gpm discharge at the base of a partially reclaimed strip mine area contributed 158 lb/day of acid to Brush Run.

Mine No. 1139

Adjacent to a county highway east of Mechanicsville a 30 gpm discharge emerged from an old mine seal. Surface indentations indicate there may have been three openings in the immediate area. The discharge has broken through to the surface adjacent to the seal. The backside of this hill has been strip mined and possibly this operation intersected the old underground workings which could also serve as a drainage course for the strip mine area. The acid load carried to the Little Piney Creek tributary was 334 lb/day.

Mine No. 1141

A strip mine located on the drainage divide between the Mill Creek and Piney Creek watersheds, approximately two miles east of Strattonville, discharged an acid load of 426 lb/day to a Brush Run tributary. The effluent flows from the base of the unreclaimed strip mine and was noticeably discolored.

Mine No. 1143

At Mine No. 1143, only limited evidence remains to suggest mine openings in this immediate area. A 15 gpm discharge was sampled from a pipe which is either located at the base of a slumped opening or serves as a drainway for a nearby mine. The acid load carried by this discharge was 135 lb/day.

Mine No. 1144

Just east of Strattonville on Route 322, a mine opening was located under the bed of the highway. The old abandoned operation was adjacent to an operating lumber mill. At this site the mill owners have ponded the mine drainage which is kept in reserve for fire emergency. The acid load carried by this 30 gpm effluent was 174 lb/day.

Mine No. 1149

Surface mine operations at the headwaters of an unnamed tributary to Brush Run contributed an acid load of 126 lb/day. The area had not been reclaimed and numerous spoil piles, rubbish dumps, and several small ponds were located within this mined area. The sample represented cumulative seepage occurring at various points along the bottom edge of the strip mine.

Mine No. 1157

An active strip operation located south of Holden contributed a net acid load of 282 lb/day to Piney Creek. The measured 105 gpm flow resulted from a pump located in the active strip cut. After discharge from the pump, the drainage was piped to two settling ponds. The flow rate based on gpm for a 24 hour day was not known, and therefore the acid load was subject to wide variation.

Mine No. 1161, 1163

In the northeast corner of the watershed, approximately 0.5 mile west of the community of Corsica, two stripped out drift openings contributed an acid load of 1,025 lb/day to the headwaters of Little Piney Creek. Contour strip operations have removed two coal seams in this area and undoubtedly destroyed drift mine openings. An active coal washery located nearby was using the lower cut of the strip mine for compaction of silt and refuse. The sample points represent probable locations of the mine portals. The discharges were artesian and flow from the base of the strip spoils. The flow rates and acid loads carried by Mine No.'s 1161 and 1163 were 60 gpm, 554 lb/day and 19 gpm, 471 lb/day, respectively.

Mine No. 1165

Immediately east of principal source No. 1173, an additional source of mine drainage emanating from the same strip mine complex, contributed an acid load of 142 lb/day to an unnamed tributary of Piney Creek. At least two coal seams have been mined at this location and numerous seepage areas occurred at the upper elevation operation. By subsurface drainage these seepage areas undoubtedly contributed to the discharges recorded at the base of the lower operation. At this point four discharges combined to total a 15 gpm flow. Only partial reclamation had been accomplished at this mine site.

Mine No. 1173

In terms of acid load, the headwaters of main stem Piney Creek received the highest single source of mine drainage pollution inventoried in the watershed. A strip mine complex, located in the northeast

corner of the watershed, contributed areas of seepage in addition to a principal source discharge of 252 gpm. This discharge was actually two side-by-side effluents originating at the base of the strip mine spoil piles. The acid load discharged to Piney Creek at this point was 1,542 lb/day. No evidence of prior deep mining at this site was indicated.

Mine No. 4207

A small seepage area located at the southwest tip of this active surface mine operation contributed an acid load of 141 lb/day to a tributary of Brush Run. Upon completion and reclamation of the operation, this pollution source may be eliminated.

Mine No. 4208

An active hilltop area strip mine overlooking the Clarion River near the mouth of Piney Creek was the source of an 858 lb/day acid load. The small unnamed tributary to Piney Creek which drains the south side of this active operation had a pH of 3.2 and a specific conductance in excess of 8,000 micromhos/cm. It was this tributary from which the mine drainage sample was obtained. It is not known whether any deep mine activity preceded the current surface mine activity.

Mine No. 4214

A mine seal located in the community of Mechanicsville discharged an acid load of 219 lb/day to an unnamed tributary of Brush Run. There are several additional abandoned mine openings in the immediate area which were dry. This suggests that the drainage from these dry mines may be channeled via underground drainways to a common discharge point, the mine seal. The flow at the seal was 60 gpm.

Mine No. 4216

An unnamed tributary to Brush Run, north of Mechanicsville received a 180 gpm discharge from an area which has experienced both surface and underground operations. At this location a small intermittent tributary had been stripped out in its headwaters area. The minimal flow of this tributary was diverted underground by way of surface fractures in the strip area, then reappeared at the base of the operation with greatly increased flow. The acid load measured below the disturbed area was 756 lb/day.

Mine No. 4218

The 30 gpm discharge from Mine No. 4218 appears to result from

a stripped out underground mine. The strip mine has been backfilled and graded. The discharge was located at the base of the reclaimed area. Deep mine refuse piles were located adjacent to the discharge point and it appears likely that the strip mine operation covered or destroyed the old mine openings. The acid load carried to the Brush Run tributary was 109 lb/day.

Mine No. 4219

A mine seal located just west of the community of Reidsburg discharged an acid load of 503 lb/day to an unnamed tributary of Piney Creek. Deposits of "yellow boy" and growths of algae were present in front of the mine seal. A dry seal was located immediately adjacent to this discharging seal.

Mine No. 4233

Approximately 0.6 mile east of Shamburg an unreclaimed circular hilltop strip mine discharged an acid load of 186 lb/day to a Piney Creek tributary. The drainage emerged from the southern tip of the mine, flowed down the side of the hill, was piped via culvert under the road, flowed across another strip mine, and finally discharged into an unnamed tributary of Piney Creek.

CLARION COUNTY

SUMMARY AND CONCLUSIONS

1. The Toby Creek watershed, draining 37 square miles of Clarion County has been severely degraded as a result of coal mine discharges. Both underground and surface mining methods are common in the watershed. The Toby Creek watershed has the additional pollution problem of abandoned gas wells whose artesian effluents have chemical characteristics similar to those of acid mine drainage..
2. The degraded water quality of Toby Creek extends the entire length of the main stem as well as affecting many miles of tributary streams. The streams draining the affected areas of the watershed are acidic, highly mineralized, and devoid of normal aquatic life.
3. Approximately 100 mining sites and an estimated 800 acres of strip-mined area were investigated during this study. Samples for chemical analysis were collected from 82 discharging sources. Discharges from these sources ranged from one to 500 gallons per minute (gpm) and totalled 3 million gallons per day (mgd). The pH values of the effluents ranged from 2.5 to 7.3 and total acidity concentrations as high as 8,330 mg/l were recorded. Only four of the effluents were alkaline. The total acid load (less alkalinity) discharged to Toby Creek and its tributaries equalled 40.5 tons per day.
4. Strip mines are the principal mine drainage pollution source in the Toby Creek watershed. Several of these strip mines are associated with small drift mines. Mine No. 1023 contributed an acid load of 49,980 lb/day, about 62 percent of the total acid load measured in the entire watershed.
5. Nineteen principal mine drainage sources contributed 95 percent of the acid load discharged to watershed streams. It is estimated that physical abatement of these principal sources should produce significant water quality improvement in Toby Creek.

DESCRIPTION OF AREA

Toby Creek rises in northeastern Clarion County, Pennsylvania and flows southwest some 14 miles to the Clarion River. The watershed drains 37 square miles located entirely in Clarion County. The

watershed is long and narrow in shape, measuring about 14 miles in length and about 4 miles at its maximum width (east-west). The principal tributaries to Toby Creek are Engle Run, Rapp Run, and Step Creek.

The Toby Creek watershed is bounded on the east and south by the Clarion River and a number of minor Clarion River tributaries, on the west by Deer Creek, and on the north by drainage to Tionesta Creek.

Mining in the Toby Creek watershed has been generally limited to operations located on the hilltops. Strip mines are especially common and many are associated with small drift mines. The majority of these operations are distributed about the perimeter of the drainage area just inside the drainage divide. There have been only limited operations in the interior portions of the watershed.

STREAM WATER QUALITY

Toby Creek and several of its tributaries are grossly polluted by coal mine drainage. The degraded water quality is evident from the uppermost reaches of the headwaters and persists over the entire downstream length of the tributary, a distance of about 14 miles. The main stem and several tributaries are acidic, highly mineralized, and devoid of normal aquatic life.

During the course of the field study several stream locations were sampled for chemical analysis (Table 26). These stations were selected to measure the cumulative effects of mine drainage. Additionally, stream sampling data collected near the mouth of Toby Creek during the 1966 stream sampling program are included. A summary of all stream data is presented in Table 27 and the stream sample locations are shown in Figure 17.

In addition to the mine discharges sampled in the Toby Creek watershed, 14 gas-well effluents were also documented. These discharges have chemical characteristics similar to coal mine discharges.

Station No. 1166

Toby Creek drainage area below Engle Run represents approximately one-half of the watershed. The total acid load carried at this point was 2,411 lb/day. The other mine drainage related parameters such as hardness, sulfate, and total iron were also found to be excessive.

123a

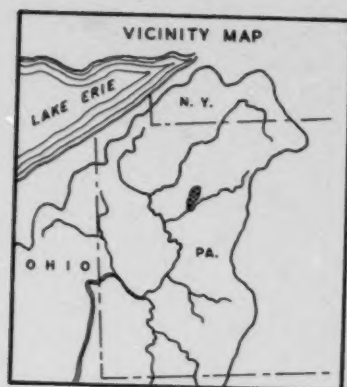


FIGURE 17

TOBY CREEK WATERSHED
CLARION COUNTY
STREAM WATER QUALITY

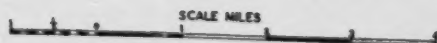


Table 26

Stream water quality sampling stations,
Toby Creek watershed Clarion County

<u>Station No.</u>	<u>Sampling Period</u>	<u>Stream</u>	<u>Location</u>
1162	June 1967	Toby Creek	Near Mouth
1166	June 1967	Toby Creek	Below Engle Run
1167	June 1967	Step Creek	Near Mouth
1168	June 1967	Rapp Run	Near Mouth
4508	Sept. 1967	Toby Creek	Above Rapp Run
0516	June, August, Sept. 1966	Toby Creek	Near Mouth

Table 27

Stream water quality data, Toby Creek watershed Clarion County

Station Number	No. of Samples	Flow (gpm)	Specific Conductance ^{4/}	Total Acidity mg/l	lb/day	Total Hardness mg/l	lb/day	Sulfate mg/l	lb/day	Total Iron mg/l	lb/day	Manganese mg/l	lb/day
1162	1	3,933	1,800	735	34,689	198	9,344	1,240	58,523	18.0	868	44.0	2,076
1166	1	1,634	625	123	2,411	138	2,705	245	4,803	2.0	33	5.4	106
1167	1	392	1,450	375	1,764	142	667	680	3,198	18.0	85	7.4	35
1168	1	49	5,000	3,515	2,087	342	203	4,380	2,601	159.0	94	148.7	88
4508	1	3,668	1,600	430	18,926	284	12,500	780	34,334	8.0	370	18.8	828
0516 ^{1/}	6 ^{2/}	4,500	2,163	970	47,582	415	20,163	964	37,446	112.3 ^{3/}	8388	38.0	1,947

^{1/} Additional sampling of Station No. 1162, conducted prior to the mine drainage source investigation.^{2/} Average of 6 samplings, 1966^{3/} Average of 4 samplings, 1966^{4/} Specific conductance measured as micromhos/cm.

Station No. 1167

The entire 3.0 square mile drainage area of Step Creek was severely degraded by mine drainage. The acid load measured at the mouth of this small tributary was 1,764 lb/day, and the sulfate and iron loadings were 3,198 lb/day and 85 lb/day, respectively.

Station No. 4508

Station No. 4508 was located on Toby Creek just above the large acid discharge at Mine No. 1023. At this point, the entire drainage area of the watershed, excepting the extreme lower parts, is represented by the stream sampling location. Approximately 9.5 tons per day of unneutralized acidity was carried by Toby Creek at this point. The sulfate load exceeded 17 tons per day and the hardness load was 6.25 tons per day.

Station No. 1168

Rapp Run, draining 1.2 square miles, discharged an acid load of approximately one ton per day to Toby Creek. The iron concentration (159 mg/l) and manganese concentration (149 mg/l) measured at the mouth of Rapp Run were the highest encountered in the Toby Creek watershed.

Station No. 0516

At its mouth Toby Creek carried excessive loadings of all mine drainage related parameters. During the 1966 stream survey Toby Creek discharged an average acid load of 23.7 tons per day to the Clarion River. In addition, Toby Creek discharged sulfate and iron loadings of 18.7 tons per day and 4.2 tons per day, respectively. The manganese load was also quite high, nearly one ton per day.

BIOLOGY

A biological evaluation of Toby Creek at Station No.'s 1162 and 0516, Toby Creek near mouth, was made during 1966 to determine the effect of pollution upon normal aquatic fauna. The benthic organisms collected consisted almost entirely of acid tolerant forms. The substrate of the stream was characterized by physical evidence of mine drainage pollution; which included red stains on rocks, sediment characteristics, and lack of biological growths.

In summary, nearly all mine drainage-affected stream locations sampled were characterized by acidic pH values below 3.6 and specific conductance values above 1,450. Alkalinity concentrations were depleted to zero and acidity concentrations ranged from 123 mg/l to 3515 mg/l. Sulfate, iron, and manganese concentrations were high at each sampling point.

Most of the watershed streams draining mined areas are characterized by red appearance and the presence of an orange-yellow precipitate in suspension or on the stream bottom. During periods of high stream runoff the streams are extremely turbid due to flushout and resuspension of stream bottom deposits that resulted from drainage of mined areas.

SOURCES OF MINE DRAINAGE

Some 100 mining and related sites and an estimated 800 acres of strip mined area were investigated during this study. Samples for chemical analysis were collected from 82 sources discharging at the time of the survey. Discharges from the coal mine sources ranged from one to 500 gpm and totalled 3 mgd. The pH of the effluents ranged from 2.5 to 7.3 and total acidity concentrations as high as 8,330 mg/l were recorded. Only 4 of the 82 discharging sources were alkaline. The total acidity loading (less alkalinity) to Toby Creek and its tributaries equalled 40.5 tons per day.

A detailed description of the mine drainage sources in the Toby Creek watershed follows. All mine location sites inventoried in the watershed are shown in Figure 18 following the source description section. Mine drainage data is shown in Appendix G.

Headwaters

The first mining operations in the Toby Creek watershed are located in the uppermost reaches of the drainage area. Three area strip mines and two drift mines were inventoried in this area. Discharges totalling 19 gpm were seeping from the bottom of two of the strip mined areas and a refuse pile. The acid load contributed by these sources (Mine No.'s 1001, 1002, and 1003) was 225 lb/day. Discharges from the two drift mines (No.'s 1004 and 1026) contributed a flow of 108 gpm and carried an acid load totalling 165 lb/day. Drift Mine No. 1026 is located within a strip mined area and the measured discharge was attributable to both mining operations. Mine No. 1003 is identified as a principal mine drainage source discussed in a later section.

Immediately south of the above mentioned area a series of three abandoned gas wells are located on the east bank of main stem Toby Creek. The three well effluents were alkaline and discharged a combined alkaline load of 54 lb/day. However these gas wells also discharge a combined iron load of some 24 lb/day, which imparts a noticeable discoloration to Toby Creek.

Another headwater tributary of Toby Creek which was severely degraded by mine drainage is located northeast of the intersection of State Routes 966 and 36. Five strip mines, four drift mines, and two abandoned gas wells were inventoried in this area. Three of the four drift openings lie within the stripped area and it is believed that the other openings were destroyed or covered during the later surface mine operations. Nine discharge points plus additional areas of seepage were located. At Mine No. 1015 a discharge of 207 gpm was flowing from the bottom of a partially reclaimed strip operation. There is evidence which suggests a drift opening was once located near this discharge point. The acid load carried to the unnamed headwater tributary was 1,155 lb/day. An acid load of 784 lb/day was discharged by Mine No. 1008, a combination underground-surface mine. The two abandoned gas wells contributed an acid load of 126 lb/day. Principal drainage sources located within this area are Mine No.'s 1008, 1014, and 1015 and are identified in a later section. The remaining four discharges from the area contributed an acid load of 56 lb/day.

Toby Creek

Near the community of Scotch Hill three area strip operations were investigated. The strip mined areas are located on the eastern boundary of the Toby Creek watershed and two of the five discharges drain out of the Toby Creek watershed and into other tributaries of the Clarion River. Total acid discharges which drained to Toby Creek (Mine No.'s 1025, 1150, and 1151) amounted to 321 lb/day. These discharges all result from accumulated seepage points at the base of the spoil piles. One drift mine was located within the stripped area but it was dry at inspection. Mine No. 1151 is classified as a principal mine drainage source.

Below Scotch Hill (south) an abandoned strip mine (Mine No. 1066) was located adjacent to Route 366. The discharge from the mine pit was sampled and the discharge was alkaline. Two other strip mine effluents from other workings discharged an acid load of 156 lb/day to an unnamed tributary of Toby Creek.

Southwest of the community of Leeper (junction of State Routes 36 and 58) a small area strip mine is located adjacent to the east side of

Route 68. Two drift mines are located within the stripped area and both were discharging at inspection. Mine No.'s 1017 and 1018 carried acid loads of 778 lb/day and 70 lb/day, respectively. Mine No. 1017 is classified as a principal source.

Engle Run

Combination underground-surface mines located at the headwaters of Engle Run (Mine No.'s 1021 and 1022) discharged combined acid loads of 340 lb/day to the tributary. The strip mined area containing Mine No. 1022 is located on the hill dividing the drainage areas of Engle Run and Toby Creek. Two seepage points from the eastern side of the area strip mine discharged an acid load of 215 lb/day to Toby Creek. Three additional mine effluents discharged an acid load of 152 lb/day to Engle Run. An abandoned gas well effluent located on a tributary to Engle Run contributed an acid load of only 3 lb/day.

Toby Creek-Main stem and tributaries

Mine No.'s 1152, 1153, and 1154, discharging to an unnamed tributary which enters Toby Creek from the west below Engle Run, were located in an area which was once deep mined and later strip mined. The 15 gpm discharge from Mine No. 1152 emerges from a drainway near an old mine tipple. The acid load carried by this discharge was 264 lb/day. The remaining two discharges result from seepage accumulation along the bottom of the partially reclaimed strip area. The combined acid load of these discharges was 69 lb/day. An abandoned gas well effluent located in this area contributed an additional acid load of 33 lb/day.

Between the mouth of the above mentioned tributary and the confluence of Step Creek with Toby Creek, there are several small unnamed tributaries to Toby Creek which were affected by mine drainage.

Near the headwaters of one tributary entering on the west bank, two discharge points were inventoried. A drift mine (Mine No. 1104) discharged an acid load of 132 lb/day to the tributary. The area immediately above the old drift opening has been strip mined and numerous seepage areas occurred about the perimeter of the operation. Since no point discharges were measurable, the receiving tributary was sampled and gaged (No. 1055). The pH of the tributary was 3.2 and it carried an acid load of 361 lb/day. This discharge is classified as a principal mine drainage source.

On the east bank of Toby Creek a hilltop area strip mine discharged a combined acid load of 143 lb/day (Mine No.'s 1056, 1057). Both discharges emerge near road level, approximately 100 feet below the

strip mined area. South of this area three strip mines, one of which was active, and one drift mine were inventoried. Strip Mine No. 1058 discharged an acid load of 2100 lb/day to an unnamed tributary of Toby Creek. Only partial reclamation had been accomplished at this site. Due to the proximity of a nearby drift mine which was dry, intersection between the two mining operations is likely. The remaining strip mines in the area, including the active strip mine, were dry. Mine No. 1058 is identified as a principal drainage source.

Step Creek

The headwaters of Step Creek arise near the community of Lucinda and are immediately degraded by mine drainage. In the sub-watershed area 14 discharging sources were inventoried. Two of the sources were abandoned gas well effluents. Acid discharges attributable to drift mines totalled 452 lb/day and surface operations contributed approximately 100 lb/day. The largest acid discharge located on Step Creek, 383 lb/day, resulted from an abandoned gas well (No. 1052) which is identified as a principal watershed drainage source.

Lower Toby Creek and Tributaries

Two abandoned gas well effluents were located on the west bank of Toby Creek just above the confluence of Step Creek and Toby Creek. The acid load discharged by these well effluents was 184 lb/day (No.'s 4257, 4258).

Below Step Creek, the next downstream tributary to Toby Creek receives significant amounts of mine drainage. Near the headwaters of the tributary an acid load of 195 lb/day was carried by a 36 gpm discharge from a reclaimed strip mine area. A second strip mined area which was used for coal storage contributed an acid load of 106 lb/day.

The unnamed tributary which drains a part of the watershed west of Miola was grossly polluted by acid mine drainage. At the headwaters of the tributary an abandoned drift mine discharged an acid load of 14 lb/day. Below this point three strip mine discharges contributed high acid loads to the tributary. The discharges from Mine No.'s 1040, 1044, and 1045 all originated at the bottom of a recently strip mined area. The operation was a hilltop strip which was backfilled, graded, and planted. If drift mines were once operative in this immediate area, all traces have been destroyed or covered by the strip mine operation. The volume of these discharges and the acid load carried by the discharges were as follows: Mine No. 1040, 65 gpm, 4,836 lb/day; Mine No. 1044, 45 gpm, 3,985 lb/day, and Mine No. 1045, 6 gpm, 265 lb/day. Below this strip area two abandoned gas wells (No.'s 1041, 1042) contributed an additional acid load of 682 lb/day

to the tributary. Mine No.'s 1040, 1044, 1045, and gas well 1041 are identified as principal watershed sources.

Rapp Run and main stem Toby Creek

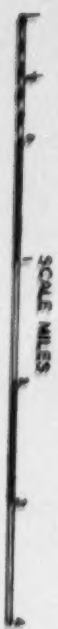
Toby Creek receives large amounts of acid mine drainage from discharge points draining directly to the main stem and from Rapp Run, the last principal tributary to Toby Creek. A large area strip mine is located on the eastern divide between the Rapp Run and Toby Creek drainages. Eleven drainage sources were located along the base of this surface mine, seven draining to Rapp Run and four draining to Toby Creek.

Mine No.'s 1034 and 1023 contributed the major part of the acid load discharged by the strip mined area which drains to Toby Creek. Mine No. 1034 discharged an acid load of 321 lb/day from the bottom of the spoil piles. Above this point a small tributary which drains to Toby Creek has been stripped out in the headwater area. In the partially reclaimed strip area only a final cut remained near the upper part of the mined area. The cut was dry near the upper end but near the lower end a discharge of 500 gpm (Mine No. 1023) emerged from the floor of the cut with a noticeable artesian effect. The discharge then followed what remained of the old tributary channel. The acid load carried by Mine No. 1023 was 49,980 lb/day with a pH of 2.8 and a conductivity of 8,000 micromhos/cm. This was the largest discharge in terms of acid load encountered anywhere in the inventoried watersheds of the Clarion River and accounted for more than 60 percent of the measured source acid load in Toby Creek. Both Mine No.'s 1034 and 1023 are identified as principal drainage sources.

Mine No. 1023 was sampled a second time, approximately 3 months later. At this time the discharge volume was 250 gpm and the acid load was 28,000 lb/day.

The six mine discharge points located in the Rapp Run drainage area contributed a combined acid load of 10,758 lb/day. Each of the six discharges originated along the perimeter of the strip mine area and drained directly to Rapp Run. Mine No.'s 1029 and 1031 were responsible for the major part of the acid load. The loads were 5,472 lb/day and 4,964 lb/day, respectively. In addition over 800 lb/day of iron was discharged to Rapp Run from these two sources.

Mine No. 1033 was the third principal watershed drainage source located in the Rapp Run area. This discharge also originated from the base of the strip mine spoil piles and carried an acid load of 475 lb/day.



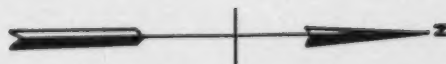
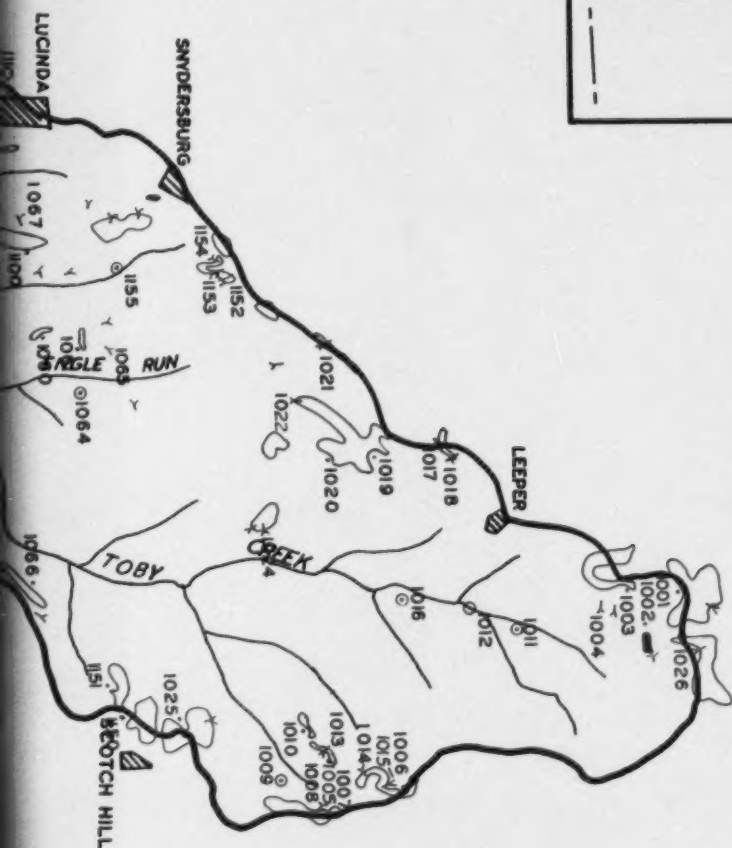
TOBY CREEK WATERSHED
CLARION COUNTY
SOURCES OF MINE DRAINAGE POLLUTION



- LEGEND—
- ABANDONED GAS WELL
 - * UNDERGROUND MINE
 - SAMPLING POINT LOCATION
 - MINE REFUSE
 - ▨ STRIP MINE

2

A vicinity map showing the location of the study area in Pennsylvania (PA.). The map includes the state boundaries of Ohio to the west and New York (N.Y.) to the east. Lake Erie is shown to the north of the study area. The study area is indicated by a shaded region within Pennsylvania.



B

DISCUSSION

Toby Creek and many of its tributaries are seriously polluted by coal mine drainage. These streams are acidic, highly mineralized, and devoid of normal aquatic life. Toby Creek is so affected from the headwaters area and over its entire downstream length to its confluence with the Clarion River.

Table 28 presents an area breakdown of mine drainage in terms of the total flow and total loadings (lb/day) of polluting constituents discharged to receiving streams in the Toby Creek watershed.

Acidity

From Table 28, a total acid load of 40.5 tons per day was discharged by 82 sources at the time of the study. More than 60 percent of this total load, 25 tons per day, was discharged directly to Toby Creek. This 25 tons per day loading was primarily attributable to Mine No. 1023. Unnamed tributaries to Toby Creek and Rapp Run received an additional acid load which exceeded 14 tons per day.

An average acid load of some 23.8 tons per day (Station No. 0516) was measured in Toby Creek downstream of all mine drainage inflow during the 1966 stream sampling program. This average load is some 16.7 tons per day less than the sum total of all the individual drainage sources measured (40.5 tons per day). This difference in acid load values is attributed to several causes. First, not all the streams in the watershed are degraded by mine drainage and the dilution and neutralization capacities of these alkaline tributaries help to reduce the acid load carried by Toby Creek. Secondly, the varying hydrologic periods under which the source inventory and stream sampling were conducted tends to exert wide variation in stream acid loadings and total source acid loads.

The variance in cumulative net acidity carried by Toby Creek near its mouth is due to periods of fluctuating stream flow. This is apparent when the maximum and minimum flow conditions and acid loads are examined. Flow rates ranged from a minimum of 3 cubic feet per second (cfs) to a maximum of 15 cfs while acid loads ranged from a minimum of 9.4 tons per day to a maximum of 36.2 tons per day. During this period the acidity concentration ranged from 735 mg/l to 1226 mg/l.

The highest acidity concentration encountered in the watershed was 8,330 mg/l from Mine No. 1023, an abandoned strip mine.

Table 28
Mine drainage loadings
Toby Creek watershed, Clarion County

Receiving Stream	Stream Mile ¹ / (sq.mi.)	Drainage Area (sq.mi.)	Number of Mine Discharges	Total Discharges (gpm)	Total Net Acidity (lb/day)	Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Toby Creek	-	-	13	651	51,153	4,922	63,256	3,970	657
Tribs. to Toby Creek	-	-	43	1,093	17,599	9,768	26,234	1,455	470
Engle Run	6.9	4.0	6	26	495	276	671	11	19
Step Creek	3.0	2.6	8	120	753	646	1,672	229	15
Tribs. to Step Creek	-	-	6	59	247	167	467	31	4
Rapp Run	0.8	1.2	6	141	10,758	865	13,590	862	159
TOTALS			82	2,090	81,005	16,644	105,890	6,558	1,324

¹ Distance above mouth of Toby Creek.

Alkalinity

Only four of the 82 mine drainage discharges inventoried contained alkalinity concentrations in excess of acidity. Three of these four discharges resulted from abandoned gas wells. Alkalinity concentrations of all stream sampling points located throughout the watershed were depleted to zero.

Hardness

A total of 8.3 tons per day of hardness was discharged to the streams of the watershed by the sources measured. This loading comprised about 80 percent of the total hardness load measured near the mouth of Toby Creek. As with other mine drainage related parameters, the major part of the hardness load was discharged to main stem Toby Creek and its unnamed tributaries. Only minor loadings of hardness are received by such tributaries as Engle Run, Step Creek, and Rapp Run.

The highest hardness concentration encountered in the watershed study was 7,600 mg/l from Mine No. 1040, an abandoned strip mine.

Ions in coal mine drainage contributing to hardness in significant amounts are calcium, magnesium, iron, manganese, and aluminum.

Sulfate

Acidic and alkaline mine water both commonly contain high concentrations of sulfate ion. The sources of sulfate in these mine effluents are sulfuric acid and dissolved sulfate salts. The sulfate content of receiving streams draining coal mining areas is indicative of the amount of total acidity that has been discharged to them through mine drainage. This sulfate content is the residual component of neutralized acidity as well as a component of acidity not yet subjected to neutralization.

A total sulfate load which approached 53 tons per day was measured in the study area. Mine No. 1023 discharged 30 tons of this total load. Unnamed tributaries to Toby Creek and Rapp Run received the major part of the remaining sulfate load.

Total Iron

At most of the stream locations for which analytical data are shown in Table 27, total iron concentrations and loads are high. An average daily load of 4.2 tons per day was measured at the mouth of Toby Creek. A total of 3.3 tons per day of iron was measured emanating

from individual mine sites. However, the iron load carried by Toby Creek is subject to wide variation (2.8 tons per day to 5.4 tons per day, 1966) and iron is commonly precipitated on the stream bottom, particularly in the lower reaches of the tributary.

Over one-half of the total iron load (3,825 lb/day) measured in the study area was discharged by a single mine, Mine No. 1023, an abandoned strip mine. The highest iron concentration encountered was 925 mg/l (Mine No. 1044).

Manganese

Similar to the occurrence of iron, manganese concentrations are excessive at all stream locations shown in Table 27. The highest stream concentration was found at Station No. 1168, Rapp Run at mouth.

An average stream load of about one ton per day was measured at the mouth of Toby Creek, while about 1.4 ton per day was discharged from the mine sites. Like iron, varying amounts of the manganese load discharged to Toby Creek and its tributaries is precipitated and deposited on stream bottoms.

Table 29 presents a summary of flow volumes and chemical loadings, by type of source, for the 82 discharging sources inventoried in the watershed.

At the time of the field survey there was only one active mine in the watershed, however, the operation was dry. The 14 discharging abandoned gas wells contributed a total acid load of nearly 0.8 tons per day.

Inactive or abandoned strip mines were the principal mine drainage pollution source type. These sources were responsible for about 92 percent of the acid load measured in the watershed. However, numerous strip mines which contribute to this acid load were associated with small underground mines. These underground mines were either destroyed and covered by the surface mines or were located in the strip mine highwall after completion of the surface mine operation.

The 43 strip mine sources (Table 29) discharged the following percentages of each parameter: flow (gpm), - 61 percent; net acidity, - 92 percent; hardness, 82 percent; sulfate, 90 percent; iron, 92 percent; manganese, 82 percent.

Table 29
Mine drainage loadings
Toby Creek watershed, Clarion County

Source Type	No.	Total Discharges (gpm)	Total Net Acidity (lb/day)	Total Hardness (lb/day)	Sulfate (lb/day)	Total Iron (lb/day)	Manganese (lb/day)
Strip Mines (abandoned)	43	1,207	75,245	13,606	95,472	6,074	1,089
Drift Mines (abandoned)	25	538	4,321	1,788	7,106	130	163
Gas Wells (abandoned)	14	345	1,439	1,250	3,312	354	72
Totals	82	2,090	81,005	16,644	105,890	6,558	1,324

Inactive or abandoned underground mines contributed about 5 percent of the total acid load measured in the watershed. As mentioned above, several of these underground mines were associated with strip mine operations.

POLLUTION ABATEMENT

From the preceding discussion it is apparent that particular mine drainage pollution abatement emphasis will have to be placed upon abandoned strip mine sources, although additional consideration must be placed upon the underground mines associated with the strip mines. Since more than 90 percent of the total watershed acidity emanates from these sources, abatement within this source category would effect significant water quality improvement in Toby Creek.

Even though strip mine sources within the watershed contribute more than 90 percent of the total acid load, these sources total 43 and do not include major discharge points which are attributable to underground mines. The recommended principal source approach to drainage abatement selects drainage sites with respect to the magnitude of their individual acid loads and the relative contribution of each source to the total watershed problem. Thus, a reduced number of sources are selected for abatement and the expected abatement efficiency level remains adequate to insure water quality improvement in the receiving streams.

For the preliminary pollution abatement program on Toby Creek, 19 sources have been selected. These 19 sources account for 95 percent of the total watershed acidity. This approach requires abatement of 24 fewer sources and includes all significant sources of acid pollution irrespective of source type. Although this approach becomes inherently more difficult due to the inclusion of underground mines and points of intersection between underground and surface mines, it would produce greater water quality improvement throughout the entire watershed area.

Abatement by source type (43 sources) would be equally successful in removing acidity from the streams of the watershed, however, due to the exclusion of significant acid discharges of a different source type, several areas of water quality concern would remain in the watershed. Particularly in this watershed, abatement by source type may not attain the expected high efficiency level usually associated with strip mine reclamation. This is due to the underground mines located within the surface mine operations.

In summary, abatement programs designed for mine drainage pollution control in the Toby Creek watershed must include both underground and surface mines or any combination of the two (principal source approach). Although the initial field survey indicates that strip mines are the major pollution source, it would undoubtedly prove erroneous to rely entirely upon strip mine reclamation for pollution control.

In order to predict the stream effect resulting from mine drainage pollution control, it is necessary to select a critical chemical parameter on which calculations may be based. Since Toby Creek is a consistently acid stream and no industrial acid sources are known in the watershed, and acidity is usually considered the single most harmful property of coal mine drainage, total stream acidity is used in this discussion to predict water quality improvement. Similar reductions in other mine drainage related parameters (hardness, sulfate, iron, manganese) are expected to be coincident with acidity reduction.

PRINCIPAL SOURCES

Nineteen sites are identified as principal watershed pollution sources (Table 30). These sources consist of four underground mines, thirteen strip mines, and two gas wells. However, many of these 17 coal mine sources are combinations of both underground and surface mines.

In the Toby Creek watershed all sites which contributed an acid load in excess of 100 lb/day are considered as principal sources.

The combined acid load of the principal sources was 77,345 lb/day, about 95 percent of the total measured acidity.

In view of the present technical unknowns involved in the abatement of underground mine drainage, present methods cannot be expected to reach a high degree of effectiveness in all cases. There are at least seven of the principal sources which involve both surface and underground mine operations (Mine No.'s 1008, 1014, 1015, 1017, 1055, 1151, and 1152). A 75 percent reduction in mine acidity from these sites by source abatement would represent significant pollution reduction.

Providing there are no interconnections with underground workings, a 90 percent reduction in acidity loading might be a reasonable expectation achievable through strip mine reclamation at the ten remaining principal source sites.

Abatement of the two gas well sources (No.'s 1041, 1052) are expected to attain a maximum degree (100 percent) of effectiveness. The sites may require only plugging or capping of the existing well casing or installation of new casing before sealing.

Table 30

Principal mine drainage sources
Toby Creek watershed, Clarion County

Mine No.	Type of mine	Flow (gpm)	pH	Specific Conductance l/ mg/l	Acidity (lb/day)	Receiving Stream
1003	Strip mine	8	2.7	5,000	2,225	Unnamed trib. to Toby Creek
1008	Drift mine	30	3.0	5,000	2,180	Unnamed trib. to Toby Creek
1014	Drift mine	20	3.4	2,600	1,125	Unnamed trib. to Toby Creek
1015	Drift mine	207	3.4	1,050	465	Unnamed trib. to Toby Creek
1017	Drift mine	62	3.0	2,500	1,047	Unnamed trib. to Toby Creek
1023	Strip mine	500	2.7	9,000	8,330	Toby Creek
1029	Strip mine	60	2.8	8,250	7,600	Rapp Run
1031	Strip mine	65	2.8	7,000	6,365	Rapp Run
1033	Strip mine	12	2.8	5,000	3,300	Toby Creek
1034	Strip mine	12	2.9	3,600	2,235	Toby Creek
1040	Strip mine	65	2.9	6,000	6,200	Unnamed trib. to Toby Creek
1041	Gas Well	24	3.4	3,500	1,775	Unnamed trib. to Toby Creek
1044	Strip mine	45	2.8	8,000	7,380	Unnamed trib. to Toby Creek
1045	Strip mine	6	3.1	5,000	3,685	Unnamed trib. to Toby Creek
1052	Gas Well	90	5.2	1,600	355	Step Creek
1055	Strip mine	90	3.2	1,020	335	Unnamed trib. to Toby Creek
1058	Strip mine	45	2.5	3,000	3,890	Unnamed trib. to Toby Creek
1151	Strip mine	15	3.2	4,500	1,270	Unnamed trib. to Toby Creek
1152	Strip mine	15	2.8	4,000	1,470	Unnamed trib. to Toby Creek
TOTALS		1,371			77,345	

l/ Specific conductance measured as micromhos/cm.

Particular emphasis should be placed on the large acid load resulting from Mine No. 1023 and the additional discharges associated with this mining site. It is not known whether underground mines were developed at this site, however, since the surface operation has virtually removed the entire hilltop any underground workings should be completely stripped out. Five principal sources carrying a total acid load of more than 61,000 lb/day are discharged from this area. Six additional minor discharges also emanate from this same area. Abatement at this single site would produce the most significant water quality improvement in the Toby Creek watershed.

Assuming the respective reductions in acid load from the above source categories, over 36 tons per day of acidity would be removed from the receiving streams of the watershed.

Such an acidity reduction of the discharge points would effect a similar reduction at the mouth of Toby Creek. This acid reduction, which is assumed through source abatement, exceeds the average acidity loading carried by Toby Creek at mouth during the 1966 stream survey (Table 27). However, such a reduction is highly unlikely due to stream flow variation and the fluctuation in the acid load discharged by the individual mine sites.

The principal source abatement approach outlined in this document (19 sources) may prove sufficient to significantly improve the water quality in the Toby Creek watershed. However, as previously stated there is insufficient water quality data available to accurately predict the cumulative effect of source abatement. A recommendation relative to the development of this necessary data is given on page 3. If further data development or technical constraints prove the infeasibility of the principal source abatement approach, as outlined, it may be necessary to add to delete sources due to the development of more valid correlations between stream water quality and stream discharge characteristics. Until such a time the principal source approach can effectively serve as the first phase or priority in a program of drainage source abatement.

The following is a more detailed description of the 19 principal sources recommended for mine drainage abatement. The locations of the principal source sites are shown in Figure 19.

Mine No. 1003

East of Tylersburg a U-shaped hilltop strip mine contributed an acid load of 213 lb/day to an unnamed headwater tributary of Toby Creek. No distinct discharge point was located in the stripped area and the drainage represents cumulative seepage along the base of the disturbed area. Any evidence of prior deep mining at this site has

been destroyed or covered by the strip mine.

Mine No. 1008

Mine No. 1008 is located at the headwater of an unnamed tributary to Toby Creek north of Scotch Hill. A caved portal and old mine timbers mark the location of this 30 gpm discharge at the northern tip of a small strip mine. The principal portion of this discharge emanates from the caved mine portal, however, small additional increments of seepage, resulting from the strip mine spoil piles are additive to the total flow. The acid load carried by this combined effluent was 784 lb/day.

Mine No.'s 1014, 1015

Both of these principal sources are drift mines located in a partially reclaimed strip mine. The two portals are near each another and probably interconnect. Mine No. 1015 had a flow of 207 gpm and an acid load of 1,155 lb/day. The discharge from Mine No. 1014 was 20 gpm and carried an acid load of 270 lb/day.

Mine No. 1017

This mine discharge was located in the northwest part of the watershed and contributed an acid load of 778 lb/day to an unnamed tributary of Toby Creek. The 62 gpm flow emerged from an old drift mine. The mining site is situated near the top of a hill dividing the Deer and Toby Creek watersheds.

Mine No. 1023

A large acid load is received by Toby Creek on the main stem side of the hilltop area strip mine dividing the Rapp Run and Toby Creek drainage areas. In the reclaimed strip area only a final cut remained. This cut was located at the headwater area of a stripped-out tributary. The cut was dry near its upper end but at the lower end a measured discharge of 500 gpm emerged from the floor of the cut and then followed what remains of the old tributary channel. The acid load carried by this discharge was 49,980 lb/day. This is the largest discharge in terms of acid load encountered anywhere in the six inventoried watersheds of the Clarion River and accounts for 62 percent of the measured source acid load in Toby Creek.

Mine No.'s 1029, 1031

These two mine drainage sources accounted for over 90 percent of the 10,758 lb/day total acid load discharged to Rapp Run by six sources. The origin of these six sources was a hill top area strip



FIGURE 19
TOBY CREEK WATERSHED
CLARION COUNTY
PRINCIPAL MINE DRAINAGE SOURCE LOCATIONS



located on the drainage divide between Rapp Run and main stem Toby Creek. The strip mine had been reclaimed but much leaching occurred along the bottom edges of the disturbed area over virtually its entire perimeter. The acidity concentrations and acid loads of Mine No.'s 1029 and 1031 were 7600 mg/l, 5,472 lb/day and 6,365 mg/l, 4,964 lb/day, respectively.

Mine No.'s 1033, 1034

These two mine discharges were located between two other principal sources, Mine No.'s 1023 and 1031. These discharges emerged from the side of the hill approximately 60 to 80 feet below the perimeter of the strip mine and discharged directly to Toby Creek. Mine No.'s 1033 and 1034, with flows of 12 gpm each, carried net acid loads of 475 lb/day and 321 lb/day, respectively.

Mine No.'s 1040, 1044, & 1045

Three additional principal mine drainage sources were located south of Mine No. 1058. The 45 gpm effluent from No. 1044 emerged from the bottom of the strip spoils at a low point in the mined area. A discharge from what appeared to be the final cut of the strip operation contributed an additional flow of 65 gpm. The smallest of the three sources, a 6 gpm discharge, emerged from the base of the strip mine in a small ravine. The acid loads carried by Mine No.'s 1040, 1044, and 1045 were 4,836 lb/day, 3,985 lb/day, and 265 lb/day, respectively. The large area strip mine responsible for these discharges had been reclaimed. The reclamation included backfilling, grading, and planting.

No. 1041

This abandoned gas well was located on the same unnamed tributary as principal source No.'s 1040, 1044, and 1045. The 24 gpm flow carried an acid load of 511 lb/day. There were several new gas wells located in this particular area of the watershed.

No. 1052

This discharge emanated from an abandoned gas well and carried an acid load of 383 lb/day to Step Creek. This gas well, located near the headwaters, had a measured flow of 90 gpm. The flow and acid load of the discharge were the largest in the Step Creek drainage area. This source accounted for 50 percent of the total acid load discharged to Step Creek.

Mine No. 1055

The 90 gpm discharge from this mine carried an acid load of 361 lb/day to an unnamed tributary of Toby Creek. The origin of this effluent was a pipe located at the base of a partially reclaimed strip mine. The strip mine, which is on the drainage divide between Step Creek and an unnamed tributary, is also associated with some underground mining.

Mine No. 1058

A small hilltop strip mine located on an unnamed tributary of Toby Creek discharged an acid load of 2,100 lb/day. Only partial reclamation had been accomplished at this mining site. An active strip mine was in operation immediately south of this older operation, however, there were no discharges inventoried during the survey.

Mine No. 1151

A hilltop area strip mine was responsible for this discharge. The strip mine had recently been reworked and partially reclaimed but this discharge and a smaller one existed from the original operation. The acid load of 228 lb/day was discharged to the headwaters of an unnamed tributary of Toby Creek.

Mine No. 1152

The drainage from Mine No. 1152 emanated from a partially reclaimed strip mine. This discharge was located near the watershed boundary of Deer and Toby Creeks and had a flow of 15 gpm. The 264 lb/day acid load was discharged to an unnamed tributary of Toby Creek.

REFERENCES

1. Ohio River Pollution Control, U. S. Public Health Service, House Document No. 26, 78th Congress, 1943, Washington, D. C., 346p.
2. Section 206, Appalachian Regional Development Act of 1965, authorized a comprehensive water resources study of the Appalachian Region.
3. The Clean Streams Law, PL 1987, Pennsylvania Legislature Act 394, June 22,, 1937, as amended.
4. Abatement of Pollution from Abandoned Mines in Pennsylvania, A Progress Report, Sanitary Water Board, Publication No. 26, March 1, 1970.
5. Pennsylvania Department of Mines and Mineral Industries - 1967 Annual Report, Bituminous Division, 231 p.

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APPENDICES

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Stream water quality-survey findings, 1966 (continued)

Station Number	Location	No. of Samples	pH	Acidity (mg/l)	Alkalinity (mg/l)	Hardness (mg/l)	Sulfate (mg/l)	Total Iron (mg/l)	Manganese (mg/l)	Flow (cfs)
519	Little Toby Cr. above Brockway (Elk County)	Min.	3.0	132.0	0.0	300.0	150.0	0.4	9.6	8.2
		Max.	3.4	296.0	0.0	619.0	950.0	60.1	13.8	20.3
		Avg.	3.2	214.0	0.0	408.8	431.7	13.3	11.7	14.6
522	East Branch Clarion River at USGS gage below reservoir.	Min.	5.5	10.0	2.0	20.0	23.0	0.1	0.5	121.0
		Max.	6.6	18.0	7.0	36.0	365.0	0.2	0.9	170.0
		Avg.	6.0	13.5	3.3	24.3	96.2	0.2	0.8	147.8
523	Clarion River at Cooksburg	Min.	5.7	1.0	10.0	50.0	15.0	0.1	0.2	232.0
		Max.	6.7	22.0	18.0	98.0	75.0	2.6	0.5	335.0
		Avg.	6.5	13.3	13.5	86.0	55.8	1.1	0.3	286.3
524	Clarion River near mouth at USCG gage	Min.	4.1	25.0	0.0	100.0	90.0	0.2	2.3	68.0
		Max.	5.3	40.0	4.0	158.0	210.0	1.4	4.4	2000.0
		Avg.	4.7	32.7	2.0	113.8	117.2	0.7	3.0	761.3

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APPENDIX B

TOBY CREEK WATERSHED
MINE DRAINAGE DATA
(Elk & Jefferson Counties)

CODES FOR TABULAR DATA

TYPE

- A - Stream
- C - Drift Mine
- D - Strip Mine
- E - Combination Drift Mine
- J - Active Operation
- * - Crop Seep

RECEIVING STREAM

- 1 - Toby Creek
- 2 - Unnamed tribs. to Toby Creek
- 3 - Limestone Run
- 4 - Brandy Camp Creek
- 6 - Kyler Run
- 7 - Walburn Run
- 9 - Mead Run
- 11 - Karnes Run
- 12 - Benninger Creek
- 13 - Sawmill Run
- 14 - Baghdad Run
- 15 - Johnson Run
- 16 - Rattlesnake Run
- 18 - Oyster Run
- 19 - McEwen Run
- 20 - Rattlesnake Creek

1-DAY CRFPA, PENNSYLVANIA - ELK COUNTY

MINE NO.	TYPE	DEC. STREAM	HA COND.	ACTIVITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW SPM
410920	C	3	2.9 1450	745 3552	0	266 1235	1040 4829	53. 245.2	14.8 68.73	387
410921	C	3	2.9 1500	545 2530	0	244 1133	820 3808	34. 157.9	8.8 40.87	387
410922	F	3	3.5 1600	535 115	0	244 63	1060 228	6. 1.2	34.8 7.52	18
410923	D	3	3.3 1900	190 5	0	200 9	500 24	16. 0.8	11.1 0.53	4
410924	C	2	2.9 2450	1445 156	0	300 32	2010 217	172. 18.6	27.0 2.92	9
410925	C	2	3.4 650	210 141	0	90 60	310 208	14. 9.1	4.0 2.69	56
410926	C	2	3.0 1500	730 1576	0	120 259	780 1684	18. 38.0	9.6 20.74	180
410927	C	2	3.1 1750	560 94	0	412 69	1040 174	15. 2.5	27.2 4.57	14
410928	C	2	2.9 2600	1025 49	0	548 26	1665 78	38. 1.8	44.8 2.15	4
410929	C	3	3.5 1000	255 67	0	258 68	550 145	10. 2.7	7.8 2.06	22
410930	E	3	4.7 560	95 34	0	210 75	285 102	3. 0.9	7.5 2.70	30
410931	C	3	7.2 265	0 0	95 12	154 20	30 3	1. 0.1	0.1 0.01	11
410932	C	3	6.9 410	18 1	61 3	168 10	145 8	2. 0.1	2.0 0.12	5
410933	F	3	6.6 220	0 0	0 0	78 16	20 4	9. 1.9	0.5 0.11	18
410934	E	3	3.4 1400	475 29	0	214 12	870 52	2. 0.1	35.4 2.12	5
410935	F	3	3.1 1300	660 97	0	266 35	825 108	12. 1.5	36.3 4.79	11
410936	F	3	3.0 2100	1285 479	0	340 126	1975 734	20. 9.3	90.0 33.48	31
410937	D	3	3.4 475	78 4	0	72 4	135 8	2. 0.1	2.6 0.16	5
410938	D	3	3.5 340	80 11	0	50 7	80 11	1. 0.1	1.4 0.20	12
410939	F	6	3.9 1400	310 1413	0	417 1901	840 3830	16. 73.0	17.0 77.52	380
410940	C	6	3.2 825	205 12	0	305 18	430 25	1. 0.1	4.1 0.25	5
410941	D	6	4.0 650	35 50	0	200 288	250 360	1. 1.4	2.0 2.88	120
410942	F	6	2.9 1500	325 15	0	318 15	720 34	12. 0.6	7.2 0.35	4
410943	E	6	3.5 375	60 6	0	108 11	160 17	1. 0.1	1.4 0.15	9

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TOBY COFFEE, PENNSYLVANIA - ELK COUNTY

MINF NO.	TYPE	REC. STREAM	PH COND.	ACIDITY MG/L LR/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LR/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM							
410944	F	6	3.0	1150	205	221	0	293	316	570	615	5.	5.2	7.9	9.53	90	
410945	C	6	3.1	1300	245	19	0	272	19	615	44	11.	0.8	8.1	0.58	6	
410946	F	6	3.2	1300	300	4762	0	254	4032	615	9763	14.	214.3	7.5	119.07	1323	
410947	C	6	5.0	220	20	0	18	0	97	4	195	9	2.	0.1	0.3	0.01	4
410948	C	6	6.0	150	45	211	4	30	52	199	45	172	3.	9.6	5.3	20.35	320
410949	F	6	3.1	900	150	12	0	250	21	440	36	6.	0.5	6.0	0.50	7	
410950	C	6	4.6	270	15	3	18	4	73	17	63	15	0.	0.1	0.5	0.14	20
410951	D	6	5.6	1200	45	1	37	0	585	14	630	15	1.	0.0	1.2	0.03	2
410952	D	6	4.8	750	35	3	5	0	307	33	340	36	1.	0.1	1.0	0.11	9
410953	D	6	3.2	75	30	0	0	0	20	0	35	0	0.	0.0	0.2	0.00	0
410954	C	6	2.6	3000	1455	1571	0	0	360	388	2100	2268	11.	11.3	70.0	75.60	90
410955	D	6	3.0	1800	845	0	0	0	255	0	1250	0	7.	0.0	37.5	0.00	0
410956	D	6	4.0	700	90	0	0	0	284	0	410	0	1.	0.0	4.5	0.00	0
410958	E	2	5.5	2200	490	999	112	228	1193	2433	1925	3927	5.	10.2	95.0	193.80	170
410959	E	2	3.1	1700	780	455	0	0	438	367	1380	1159	92.	77.3	32.0	26.88	70
410960	C	1	3.5	1200	315	1512	0	0	310	1488	705	3384	13.	61.9	12.3	59.04	400
410961	F	1	4.5	750	120	86	0	0	270	194	400	288	1.	0.5	9.7	6.98	60
410962	C	1	4.5	650	110	330	0	0	295	885	400	1200	7.	21.0	2.0	6.00	250
410963	C	1	3.2	1200	345	215	0	0	242	151	705	439	25.	15.6	4.3	2.68	52
410964	C	1	3.7	625	110	2	0	0	232	5	220	5	1.	0.0	2.1	0.05	2
410965	C	1	4.7	625	31	4	4	0	320	46	330	47	0.	0.0	0.9	0.13	12
410966	C	1	3.1	700	126	90	0	0	166	119	300	216	5.	3.7	2.0	1.44	60
410967	C	1	3.3	600	80	6	0	0	105	8	200	16	2.	0.2	1.8	0.15	7

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TORY CREEK, PENNSYLVANIA - ELK COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
410942	C	1	4.6	580	50	19	2	0	223	85	280	107	1.	0.2	3.6	1.38	32
410943	C	1	3.6	1350	355	255	0	0	371	267	900	648	18.	13.0	24.0	17.28	60
410970	F	1	3.1	1250	240	96	0	0	365	135	690	256	6.	2.2	10.8	4.02	31
410971	D	1	3.5	825	210	151	0	0	215	154	500	360	1.	0.9	7.2	5.18	60
410972	D	1	3.7	740	170	100	0	0	186	156	390	327	0.	0.2	4.6	3.86	70
410973	C	1	2.7	1250	250	30	0	0	185	22	525	63	8.	0.9	2.7	0.32	10
410974	D	1	3.3	1100	220	105	0	0	263	126	570	273	1.	0.6	3.5	1.68	40
410975	D	1	3.8	900	180	432	0	0	245	588	490	1176	4.	9.1	4.2	10.08	200
410976	C	1	3.0	1300	325	448	0	0	232	334	645	928	14.	19.9	3.2	4.61	120
410977	C	1	3.0	1200	235	169	0	0	232	167	585	421	14.	10.2	3.0	2.16	60
410978	C	1	3.2	1500	410	295	0	0	311	223	885	637	15.	10.8	12.8	9.22	60
410979	C	1	2.9	1800	440	10	0	0	265	6	850	20	12.	0.3	7.5	0.18	2
410980	C	1	3.4	1150	255	12	0	0	281	13	630	30	3.	0.2	6.0	0.29	4
410981	C	1	3.0	1150	380	45	0	0	272	32	810	97	9.	1.1	7.5	0.90	10
410982	D	6	9.6	900	50	2	0	0	377	18	480	23	1.	0.0	2.0	0.10	4
410983	C	2	3.6	450	50	2	0	0	111	5	170	8	3.	0.1	1.8	0.09	4
410984	C	2	4.6	1600	465	3543	0	0	442	3368	1120	8534	70.	533.4	15.8	120.40	635
410985	E	2	3.3	1500	400	14	0	0	277	9	870	31	11.	0.4	33.0	1.19	3
410986	D	1	6.7	680	15	5	86	30	324	116	320	115	1.	0.5	3.1	1.12	30
410987	D	1	5.6	390	35	94	5	13	169	456	190	513	0.	0.3	3.1	8.37	225
410988	F	11	6.1	800	22	2	7	0	416	39	460	44	0.	0.0	0.3	0.03	8
410989	D	11	3.4	2000	500	12	0	0	1010	24	1425	34	1.	0.0	85.0	2.04	2
410990	D	11	3.5	2000	545	6	0	0	784	9	1575	18	1.	0.0	0.0	0.00	1
410991	D	12	3.1	350	285	6	0	0	117	2	650	15	1.	0.0	15.5	0.37	2

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TOBY CRK, PENNSYLVANIA - ELK COUNTY

MINE NO.	TYPE	DEC. STAMP	PH COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM			
410992	D	12	3.7	380	170	0	0	0.0	1.4	0			
410993	C	12	3.7	1750	391	4	0	888	10	1172	14	0	
410994	C	12	4.9	300	65	14	2	0	111	23	123	26	0
410995	F	4	4.5	800	92	110	0	0	390	468	445	534	4
410996	F	4	2.8	1200	290	4008	0	0	262	3621	645	8916	29
410997	F	4	2.6	1500	440	316	0	0	278	200	880	633	20
410998	C	4	3.1	1400	300	1020	0	0	316	834	904	2386	35
410999	F	4	3.7	430	75	10	0	0	140	20	212	30	2
411000	C	4	5.8	950	75	292	0	0	396	1544	504	1965	15
411184	F	2	3.6	2200	520	748	0	0	875	1260	1375	1980	10
411185	C	13	3.4	2200	525	107	0	0	715	145	1450	295	5
411186	C	13	5.4	2200	497	95	124	23	1000	192	1475	283	4
411187	C	1	2.8	2500	475	3564	0	0	630	3326	1470	7761	10
411188	C	1	3.0	1100	190	4	0	0	218	5	465	11	5
411189	C	13	2.4	3500	1715	61	0	0	501	18	2160	77	194
411190	C	13	2.5	1500	425	5	0	0	119	1	620	7	25
411191	C	13	3.4	800	175	6	0	0	174	6	370	13	3
411192	C	14	6.3	280	0	0	68	1	109	2	57	1	1
411193	C	14	3.5	560	50	7	0	0	172	24	217	31	1
411194	E	14	3.2	400	78	10	0	0	130	17	163	21	0
411195	C	7	3.0	1000	165	89	0	0	325	175	526	284	5
411196	C	7	2.8	1000	250	120	0	0	160	76	440	211	1
411197	C	2	2.8	950	165	15	0	0	102	9	252	24	4
411198	C	1	6.7	420	0	0	42	4	181	17	128	12	2

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TORY CREEK, PENNSYLVANIA - ELK COUNTY

MINE "C" TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM							
411199	C	9	7.3	280	15	9	23	14	104	67	88	57	0.	0.1	0.2	0.13	54
411200	C	9	7.2	170	8	0	17	0	66	0	52	0	1.	0.0	0.0	0.00	0
411201	C	9	3.5	6000	2370	113	0	0	2310	110	5475	262	3.	0.1	99.9	4.80	4
411202	C	9	7.6	450	0	0	36	90	193	486	180	453	3.	7.8	2.2	5.54	210
411203	C	9	5.7	900	140	5	0	0	320	11	450	16	0.	0.0	36.4	1.31	3
411204	C	9	4.7	850	79	1	2	0	360	8	430	10	0.	0.0	9.0	0.22	2
411205	C	4	3.8	610	61	8	0	0	236	33	282	40	1.	0.1	6.4	0.92	12
411206	F	4	2.5	1800	680	179	0	0	200	52	1035	273	53.	13.9	3.1	0.82	22
411207	D	4	3.4	810	195	0	0	0	174	0	450	0	2.	0.0	15.4	0.00	0
411208	C	4	3.5	320	60	0	0	0	56	0	125	1	1.	0.0	2.0	0.02	1
411209	D	15	3.8	920	245	5	0	0	236	5	500	12	0.	0.0	22.4	0.54	2
411210	C	15	5.8	580	61	1	52	1	152	3	180	4	32.	0.8	8.2	0.20	2
411211	D	15	5.5	925	16	0	91	2	452	10	460	11	4.	0.1	9.6	0.23	2
411212	C	15	5.4	650	65	0	10	0	282	3	305	3	3.	0.0	15.3	0.18	1
411213	CJ	16	6.5	550	3	3	30	36	276	331	245	294	4.	4.2	0.2	0.24	100
411214	CJ	16	3.0	2000	480	57	0	0	416	49	1160	139	64.	7.7	1.8	0.22	10
411215	F	16	6.5	650	9	1	114	13	306	36	240	28	3.	0.3	0.4	0.05	10
411216	C	16	7.4	825	0	0	40	5	454	59	390	51	3.	0.3	0.2	0.03	11
411217	D	16	4.1	400	52	0	0	0	132	0	155	0	1.	0.0	1.6	0.00	0
411218	C	18	6.7	580	39	28	48	34	306	220	260	187	1.	0.4	0.2	0.14	60
411219	A	0	3.5	1150	215	2345	0	0	278	3032	600	6544	8.	85.1	9.4	102.54	909
411220	A	0	3.2	1600	540	2656	0	0	327	1608	980	4821	23.	115.1	22.0	108.24	410
411221	A	0	3.3	1350	375	5346	0	0	280	3991	705	10050	13.	182.5	9.6	136.86	1188
411222	A	0	3.7	600	100	7846	0	0	190	14908	250	19617	4.	298.2	4.6	360.95	6539

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TOBY COPEL, PENNSYLVANIA - ELK COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM
411223	A	0	3.8	625	75 16883	0	194 41433	270 60798	1.	315.3 6.8 1531.22	18765
411224	A	0	4.1	450	45 16283	0	143 51745	195 70562	1.	434.2 4.2 1519.81	30155
411228	C	16	6.4	600	56 73 117	154	164 216	210 277	1.	0.7 0.1 0.13	110
411239	C	15	5.4	440	53 0 10	0	160 1	100 1	2.	0.0 7.7 0.09	1
411240	C	9	7.0	850	20 31 40	62 436 680	370 577	9.	13.6 6.4 9.98	130	
411241	*	2	6.6	130	17 0 37	0 40 0	20 0	10.	0.2 1.8 0.04	2	
411242	C	1	3.8	350	44 1 0	0 128 4	125 4	0.	0.0 1.0 0.04	3	
411243	C	14	3.5	300	46 1 0	0 79 1	88 2	0.	0.0 1.2 0.03	2	
411244	D	1	6.4	120	3 0 20	0 68 2	57 2	2.	0.1 2.2 0.08	3	
411245	D	20	3.0	1300	275 9 0	0 273 9	600 21	5.	0.2 16.6 0.60	3	
411246	F	16	3.0	1500	340 122 0	0 300 108	700 252	2.	0.8 3.0 1.08	30	
411247	F	19	3.5	640	100 1 0	0 224 2	305 3	1.	0.0 2.1 0.03	1	
411248	C	14	6.9	850	0 0 53	190 472 1699	400 1440	1.	1.8 0.2 0.72	300	
411250	C	16	3.3	350	40 0 0	0 90 0	105 0	2.	0.0 0.4 0.00	0	
411251	C	16	2.9	1400	310 89 0	0 392 112	700 201	12.	3.5 1.4 0.40	24	
411252	CJ	16	5.5	950	75 81 2	2 480 518	580 626	5.	5.2 0.8 0.86	90	
411253	C	16	6.4	950	31 1 20	1 525 31	500 30	1.	0.1 0.0 0.00	5	

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APPENDIX C

DEER CREEK WATERSHED
MINE DRAINAGE DATACODES FOR TABULAR DATA

<u>TYPE</u>	<u>RECEIVING STREAM</u>
A - Stream	1 - Deer Creek
B - Gas Well	2 - Tribs. to Deer Creek
C - Drift Mine	3 - Paint Creek
D - Strip Mine	4 - Tribs. to Paint Creek
E - Combination Drift Mine	5 - Frills Run
F - Combination Strip Mine	6 - Little Paint Creek
G - Coal Preparation Plant	7 - Tribs. to Little Paint Creek
J - Active	8 - Judith Run
* - Oil Well	9 - Tribs. to Judith Run
** - Unknown	10 - Step Run
	11 - Mahles Run
	12 - Little Deer Creek

DEER CREEK WATERSHED - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH ⁺ COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANFSE MG/L LB/DAY	FLOW GPM						
411043	C	4	2.6	6000	4340	437	0	1100	211	6000	1152	165.	31.7	99.9	10.18	16
414253	C	A	2.7	8000	9235	1994	0	665	143	11375	2457	1045.	225.7	99.9	21.58	18
414254	B	3	5.9	1600	125	19	0	568	88	9800	1528	37.	5.7	5.6	0.87	13
414259	C	6	3.5	800	148	4	0	250	9	400	14	62.	2.2	2.6	0.09	3
414319	D	2	3.6	280	70	0	0	43	0	95	0	1.	0.0	1.0	0.00	0
414320	E	1	3.8	285	85	0	0	15	0	90	0	0.	0.0	1.8	0.00	0
414321	GJ	1	3.1	1600	450	374	0	615	442	1020	734	36.	25.9	13.2	9.50	60
414322	DJ	2	2.5	4000	2540	0	0	500	0	3000	0	428.	0.0	48.0	0.00	0
414323	E	2	2.3	5500	4800	0	0	122	0	5175	0	1450.	0.0	54.0	0.00	0
414324	C	2	2.4	6000	3925	94	0	715	17	4800	115	1250.	30.0	72.0	1.73	2
414325	E	2	2.5	1200	2580	309	0	1440	172	3850	462	750.	90.0	99.0	11.88	10
414326	E	8	3.2	3200	640	23	0	1700	61	2120	76	81.	2.9	54.4	1.96	3
414327	E	8	2.8	4100	1820	131	0	1280	92	3100	223	43.	3.1	87.7	6.31	6
414328	D	8	2.8	5100	2650	222	0	1260	105	5025	422	368.	30.9	99.9	8.39	7
414329	D	8	2.6	3000	985	11	0	750	9	1610	19	46.	0.6	48.3	0.58	1
414330	E	9	2.7	2100	820	9	0	840	10	1150	13	15.	0.2	39.5	0.47	1
414331	D	12	2.5	3000	1480	53	0	550	19	1855	66	128.	4.6	73.5	2.65	3
414332	E	9	2.6	4700	2485	149	0	460	27	2580	154	635.	38.1	21.0	1.26	5
414333	E	12	2.7	2400	1045	12	0	365	4	1170	14	16.	0.2	35.4	0.42	1
414334	F	12	2.6	2100	900	32	0	330	11	1125	40	33.	1.2	29.0	1.04	3
414335	E	12	4.3	440	350	4	0	27	0	205	2	17.	0.2	2.2	0.03	1
414336	D	2	2.8	2300	1045	25	0	195	4	1170	28	18.	0.4	31.2	0.75	2
414337	B	8	5.3	2400	740	888	0	615	738	1260	1512	218.	261.0	17.4	20.88	100

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NEER COPEL WATERSHED - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
414338	B	2	6.9	560	24	14	59	35	65	39	55	33	7.	4.3	0.7	0.42	50
414339	B	2	6.8	600	29	0	22	0	158	1	230	2	13.	0.2	1.4	0.02	1
414340	D	2	2.7	1300	695	0	0	0	188	0	720	0	29.	0.0	12.0	0.00	0
414341	D	2	2.8	3000	1440	51	0	0	582	20	2320	83	68.	2.4	80.0	2.88	3
414342	D	2	4.2	250	65	0	0	0	25	0	75	0	0.	0.0	1.3	0.00	0
414343	D	2	2.7	3500	1960	23	0	0	268	3	2340	28	86.	1.0	90.9	1.09	1
414344	C	1	2.3	8250	6685	80	0	0	474	5	10250	123	435.	5.2	99.9	1.20	1
414345	D	2	7.4	250	29	0	10	0	91	0	85	0	3.	0.0	1.8	0.00	0
414346	D	2	7.3	230	36	0	5	0	73	0	95	0	0.	0.0	6.0	0.00	0
414347	F	2	3.8	1500	485	0	0	0	180	0	740	0	2.	0.0	22.4	0.00	0
414348	E	2	3.8	1200	255	76	0	0	310	93	510	153	47.	14.2	5.7	1.71	25
414349	C	7	7.4	400	0	0	84	1	131	1	95	1	0.	0.0	0.8	0.01	1
414500	D	7	3.6	270	45	0	0	0	62	0	65	0	0.	0.0	1.0	0.00	0
414501	D	6	3.0	8000	4035	193	0	0	3040	145	7400	355	1450.	69.6	99.9	4.80	4
414502	D	3	2.9	8000	910	65	0	0	595	42	10125	729	1250.	90.0	99.9	7.19	6
414503	D	3	3.0	2600	1325	15	0	0	280	3	1560	18	96.	1.2	34.2	0.41	1
414504	GJ	3	2.5	3500	2030	0	0	0	224	0	2250	0	313.	0.0	21.6	0.00	0
414505	**	3	3.7	2300	680	97	0	0	635	91	1140	164	296.	42.6	13.8	1.99	12
414506	**	3	3.3	2400	690	207	0	0	685	205	1200	360	304.	91.2	13.2	3.96	25
414507	**	3	4.2	2500	710	306	0	0	725	313	1500	648	425.	183.6	12.6	5.44	36
414509	C	11	2.6	2600	1225	44	0	0	145	5	1350	48	305.	11.0	6.0	0.22	3
414510	B	11	6.4	390	17	8	43	21	93	46	90	45	0.	0.0	0.0	0.00	42
414511	C	11	2.9	1700	625	22	0	0	225	8	860	30	73.	2.6	7.2	0.26	3
414512	C	10	2.9	1200	365	4	0	0	72	0	435	5	54.	0.6	1.8	0.02	1

DEER CREEK WATERSHED - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM					
414513	B	4	5.0	1900	525	126	0	540	129	1300	312	330.	79.2	18.5	4.44	20
414514	R	3	2.8	2400	595	107	0	685	123	1350	243	300.	54.0	16.2	2.92	15
414515	D	10	3.1	2200	1260	45	0	188	6	1650	59	13.	0.5	23.5	0.85	3
414516	R	5	5.4	1700	430	619	0	650	936	1120	1612	231.	332.6	29.6	42.62	120
414517	D	10	3.0	1200	395	7	0	124	0	555	0	4.	0.0	11.1	0.00	0
414518	*	10	6.3	1200	200	60	0	335	100	600	180	35.	10.5	10.2	3.06	25
414519	D	10	3.2	800	215	2	0	147	1	350	4	3.	0.0	8.0	0.10	1
414520	D	4	2.3	6500	4270	358	0	504	42	6075	510	755.	63.4	99.9	8.39	7
414521	D	4	2.4	6000	3550	127	0	1030	37	5850	210	730.	26.3	99.9	3.60	3
414522	D	4	3.2	1400	495	5	0	165	1	735	8	5.	0.1	24.9	0.30	1
414523	F	4	2.8	4000	1340	32	0	300	7	1500	36	135.	3.2	22.0	0.53	2
414524	F	4	2.8	3000	1555	37	0	1660	39	3290	78	260.	6.2	90.3	2.17	2
414525	C	2	3.2	3000	1400	16	0	525	6	1880	22	14.	0.2	32.8	0.39	1
414526	C	4	3.4	5000	2320	250	0	935	100	2940	317	36.	3.9	85.2	9.20	9
414527	C	4	3.0	4500	2890	104	0	640	23	3300	118	230.	8.3	90.0	3.24	3
414528	C	4	2.3	7000	3100	37	0	208	2	3125	37	830.	10.0	7.5	0.09	1
414529	C	4	2.3	4500	2995	35	0	115	1	2700	32	630.	7.6	3.6	0.04	1
414530	C	4	2.7	2600	1195	63	0	322	11	1225	44	178.	6.4	8.4	0.30	3
414531	B	4	2.5	1275	290	1722	0	224	1330	460	2732	28.	168.7	10.0	59.40	495
414532	B	4	2.6	1200	280	712	0	214	544	440	1119	20.	50.9	10.0	25.44	212
414533	C	4	2.5	3000	3135	37	0	114	1	1920	23	930.	11.2	32.0	0.38	1
414534	B	6	7.0	700	0	0	90	5	124	7	140	8	0.4	1.4	0.08	5
414535	D	4	3.5	650	200	2	0	62	0	220	2	1.	0.0	3.8	0.05	1
414536	C	4	3.5	1000	300	0	0	129	0	435	0	5.	0.0	14.1	0.00	0

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DEER CREEK WATERSHED - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
414575	C	4	3.8	1500	815	19	0	0	355	8	940	22	2.	0.0	28.8	0.69	2
414581	C	3	2.7	3600	1715	0	0	0	158	0	1800	0	256.	0.0	19.2	0.00	0
414586	A	0	3.3	900	245	2518	0	0	142	1349	350	3326	3.	30.4	9.0	85.94	792
414587	A	0	2.9	900	160	8968	0	0	141	7903	310	17376	5.	280.3	7.4	414.78	4671
414588	A	0	2.8	845	245	21756	0	0	89	7593	280	23889	3.	290.1	7.0	597.24	7110
414594	A	0	3.1	1000	190	759	0	0	135	539	405	1618	5.	21.6	10.8	43.16	333
414596	A	0	3.0	800	140	7914	0	0	129	6380	270	13355	5.	237.4	6.4	316.57	4122

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APPENDIX D

LICKING CREEK WATERSHED
MINE DRAINAGE DATA

CODES FOR TABULAR DATA

TYPE

A - Stream
B - Gas Well
C - Drift Mine
D - Strip Mine
E - Combination Drift Mine
F - Combination Strip Mine
J - Active Operation

RECEIVING STREAM

1 - Licking Creek
2 - Unnamed tribs to Licking Creek
3 - Cherry Run
4 - Unnamed tribs to Cherry Run
5 - Little Licking Creek
6 - Unnamed tribs to Little Licking Creek
7 - Anderson Run
8 - Unnamed tribs to Anderson Run
9 - Mineral Run
10 - Unnamed tribs to Mineral Run
11 - Craggs Run
12 - Unnamed tribs to Craggs Run

LICKING CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
411225	D	3	3.3	1750	535	57	0	420	45	1120	120	8.	0.9	27.2	2.94	9	
411226	D	3	3.3	3500	1045	25	0	1380	33	2640	63	7.	0.2	99.9	2.40	2	
411227	D	3	6.6	2750	410	196	18	8	1640	787	1925	924	4.	1.7	12.6	6.05	40
411228	C	3	3.0	3600	1165	13	0	0	1350	16	2880	34	298.	3.6	53.1	0.64	1
411229	D	3	3.4	1600	300	3	0	0	567	6	960	11	5.	0.1	20.0	0.24	1
411230	D	3	3.9	1700	240	14	0	0	772	46	1260	75	2.	0.1	23.6	1.42	5
411231	D	3	5.8	1200	115	20	6	1	560	100	810	145	5.	0.9	19.5	3.51	15
411232	D	3	5.9	420	40	0	5	0	175	2	210	2	4.	0.1	3.4	0.04	1
411233	D	3	4.9	1100	195	18	0	0	390	37	660	63	9.	0.9	13.2	1.27	8
411234	D	3	6.3	240	0	0	48	2	89	5	45	2	0.	0.0	0.2	0.01	5
411235	D	3	6.0	650	42	1	5	0	220	5	320	7	0.	0.0	3.6	0.09	2
411236	D	3	6.5	350	0	0	70	0	82	0	60	0	15.	0.2	1.8	0.02	1
411237	D	3	4.0	1100	110	0	0	0	425	0	690	0	2.	0.0	13.5	0.00	0
414285	D	2	4.2	360	81	0	0	0	260	0	150	0	0.	0.0	3.3	0.00	0
414286	D	2	3.5	410	140	0	0	0	68	0	150	0	2.	0.0	3.1	0.00	0
414287	D	2	3.7	325	60	0	0	0	476	0	120	0	1.	0.0	2.1	0.00	0
414288	D	1	7.3	950	2	0	50	1	260	6	220	5	6.	0.1	3.8	0.09	2
414289	D	1	8.2	1100	8	0	79	0	570	0	510	0	1.	0.0	7.5	0.00	0
414290	D	1	2.8	2400	1325	0	0	0	158	0	1590	0	254.	0.0	19.6	0.00	0
414291	D	1	3.2	1900	680	0	0	0	395	0	1300	0	22.	0.0	39.0	0.00	0
414292	E	1	3.0	1900	780	9	0	0	139	1	875	10	176.	2.1	11.0	0.13	1
414293	D	2	3.1	600	145	0	0	0	57	0	225	0	24.	0.0	2.2	0.00	0
414294	D	2	3.2	5300	1785	42	0	0	1480	35	4550	109	7.	0.2	99.9	2.40	2
414295	D	2	2.9	3000	1290	46	0	0	730	26	3045	109	11.	0.4	99.9	3.60	3

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LICKING CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANFSE MG/L LB/DAY	FLOW GPM					
414296	D	2	2.6	1900	625	30	0	500	24	1350	64	60.	2.9	21.5	1.03	4
414297	D	2	2.7	2500	750	0	0	815	0	1825	0	4.	0.0	44.0	0.00	0
414298	D	2	2.6	1700	695	0	0	220	0	900	0	5.	0.0	23.2	0.00	0
414299	D	2	2.5	2500	1200	0	0	365	0	1750	0	15.	0.0	52.5	0.00	0
414300	D	2	3.0	850	220	0	0	280	0	400	0	5.	0.0	10.2	0.00	0
414301	D	2	31.0	6500	1900	0	0	59	0	235	0	3.	0.0	2.8	0.00	0
414302	D	2	3.6	390	75	9	0	87	10	135	16	1.	0.1	2.2	0.26	10
414303	D	2	3.7	350	100	0	0	61	0	110	0	1.	0.0	1.8	0.00	0
414304	D	1	3.5	1250	310	18	0	350	21	780	46	3.	0.2	18.0	1.08	5
414305	D	2	3.7	650	300	0	0	200	0	330	0	5.	0.0	6.8	0.00	0
414306	D	12	2.9	2100	585	0	0	605	0	1400	0	7.	0.0	30.5	0.00	0
414307	D	2	5.9	675	38	0	7	320	3	360	4	0.	0.0	10.3	0.12	1
414308	F	2	2.4	3500	1665	0	0	830	0	2340	0	113.	0.0	67.5	0.00	0
414309	E	2	3.0	5500	2000	24	0	2270	27	4200	50	7.	0.1	99.9	1.20	1
414310	D	2	2.4	3500	1730	0	0	675	0	2745	0	64.	0.0	99.9	0.00	0
414311	D	12	2.7	1300	340	0	0	247	0	645	0	8.	0.0	15.0	0.00	0
414312	D	12	3.2	2400	715	42	0	735	44	1560	93	21.	1.2	52.2	3.13	5
414313	D	12	3.4	5000	1000	12	0	1070	12	2040	24	2.	0.0	69.6	0.84	1
414314	D	2	2.8	6000	5070	244	0	940	45	6000	288	228.	10.9	99.9	4.80	4
414315	D	12	4.6	1600	300	3	0	764	9	1140	13	6.	0.1	29.2	0.35	1
414316	E	11	2.7	5900	3125	112	0	1180	42	4500	162	525.	18.9	75.0	2.70	3
414317	C	1	3.0	5000	1930	347	0	1490	268	3540	637	360.	64.8	66.0	11.88	15
414375	D	4	6.7	525	45	2	15	254	15	250	15	1.	0.0	2.1	0.13	5
414376	C	4	6.9	290	23	0	64	118	1	55	0	1.	0.0	1.0	0.01	1

LICKING CREEK, PENNSYLVANIA - CLARTON COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
414377	D	4	6.9	1150	78	4	63	3	540	32	630	37	5.	0.3	18.0	1.08	5
414378	D	4	4.2	500	84	1	0	0	200	2	260	3	2.	0.0	2.0	0.02	1
414379	D	4	5.7	580	18	0	26	0	277	9	270	9	2.	0.1	1.8	0.06	3
414380	D	4	3.7	625	160	7	0	0	133	6	290	13	5.	0.3	6.1	0.29	4
414381	D	4	4.0	280	95	0	0	0	46	0	100	0	1.	0.0	2.6	0.00	0
414382	D	4	3.7	1600	175	37	0	0	948	204	1220	263	2.	0.5	15.2	3.28	18
414383	D	4	3.5	1350	175	10	0	0	605	36	885	53	1.	0.0	15.0	0.90	5
414384	D	4	5.7	2200	300	0	0	0	1250	0	1750	0	12.	0.0	42.5	0.00	0
414385	D	4	3.6	600	55	2	0	0	252	12	290	13	0.	0.0	1.8	0.09	4
414386	D	4	3.6	1450	470	5	0	0	420	5	885	10	2.	0.0	26.1	0.31	1
414387	D	4	5.5	1100	20	0	28	0	612	0	555	0	0.	0.0	0.3	0.00	0
414388	D	4	3.5	2300	445	10	0	0	1035	24	1410	33	0.	0.0	40.8	0.98	2
414389	D	4	6.2	1750	125	30	15	3	950	228	1100	264	4.	1.0	24.4	5.86	20
414391	E	4	5.8	1300	83	59	0	0	610	439	750	540	7.	5.2	8.4	6.05	60
414392	E	4	5.9	1300	99	23	0	0	710	170	795	190	9.	2.2	9.0	2.16	20
414393	D	3	5.4	1100	50	4	12	1	655	62	735	70	2.	0.1	13.8	1.32	8
414394	D	3	4.3	680	40	0	0	0	320	0	350	0	0.	0.0	5.7	0.00	0
414395	C	3	3.4	1300	31	0	0	0	562	13	720	17	24.	0.6	9.0	0.22	2
414396	D	3	5.8	1200	100	2	0	0	610	14	675	16	17.	0.4	8.1	0.19	2
414397	D	3	4.4	1050	70	0	0	0	590	0	650	0	0.	0.0	2.4	0.00	0
414398	D	4	5.4	2300	0	0	95	0	1785	0	1750	0	3.	0.0	26.0	0.00	0
414399	D	4	6.3	2300	69	0	3	0	1750	0	1550	0	1.	0.0	18.5	0.00	0
414400	D	3	4.2	1500	143	0	0	0	835	0	300	0	1.	0.0	6.8	0.00	0
414401	D	3	6.1	800	0	0	65	3	464	27	440	26	0.	0.0	4.2	0.25	5

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LICKING CREEK, PENNSYLVANIA - CLARTON COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
414402	D	3	3.7	1800	585	7	0	744	8	1550	18	1.	0.0	26.0	0.31	1	
414403	D	4	6.1	1000	60	0	4	0	546	6	620	7	10.	0.1	13.4	0.16	1
414404	D	4	5.4	950	0	0	53	15	530	159	510	153	2.	0.6	6.6	1.98	25
414405	D	2	5.8	1400	6	0	33	5	905	141	840	131	1.	0.1	7.8	1.22	13
414406	F	4	3.7	1500	218	94	0	0	845	365	1140	492	30.	13.1	13.6	5.88	36
414407	D	4	6.1	1500	127	12	5	0	1770	169	1380	132	0.	0.0	33.2	3.19	8
414408	D	4	5.8	650	48	0	2	0	316	3	350	4	2.	0.0	2.0	0.02	1
414409	D	4	6.2	825	14	1	27	1	425	30	460	33	2.	0.1	6.0	0.43	6
414410	D	4	3.2	1500	215	2	0	0	540	6	940	11	4.	0.0	8.8	0.11	1
414411	D	4	7.2	345	0	0	70	6	168	16	355	34	2.	0.2	0.8	0.08	8
414412	E	4	3.2	3000	1715	123	0	0	555	39	2520	181	360.	25.9	10.5	0.76	6
414413	D	4	3.5	1900	305	43	0	0	865	124	1300	187	12.	1.7	26.0	3.74	12
414414	F	1	3.7	1350	185	8	0	0	900	43	870	41	1.	0.1	6.6	0.32	4
414415	D	2	4.0	900	85	1	1	0	405	4	520	6	0.	0.0	6.0	0.07	1
414416	D	2	3.4	750	100	0	0	0	244	0	520	0	0.	0.0	4.8	0.00	0
414417	D	2	3.0	1550	260	0	0	0	510	0	840	0	4.	0.0	6.0	0.00	0
414418	D	2	3.5	1100	260	0	0	0	331	0	570	0	3.	0.0	2.4	0.00	0
414419	D	4	3.7	1050	195	0	0	0	395	0	580	0	1.	0.0	3.2	0.00	0
414420	C	3	3.3	2300	770	36	0	0	750	36	1320	63	70.	3.3	16.2	0.78	4
414421	C	3	3.3	2000	605	7	0	0	710	8	1375	16	51.	0.6	18.0	0.22	1
414422	D	3	2.9	3250	1480	35	0	0	625	15	2160	51	74.	1.8	33.6	0.81	2
414423	F	5	3.9	1650	440	26	0	0	550	33	1060	63	116.	7.0	8.8	0.53	5
414424	CJ	5	4.5	2700	285	27	0	0	1550	148	1960	188	23.	2.2	25.9	2.49	8
414425	D	4	5.8	1300	22	2	0	0	610	58	20	1	1.	0.1	0.1	0.01	8

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LICKING CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STRAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
414426	D	4	6.2	1500	119	1	43	0	800	9	860	10	6.	0.1	50.0	0.60	1
414427	D	4	6.5	1700	77	1	36	0	980	23	1100	26	20.	0.5	19.2	0.46	2
414428	D	4	5.5	2400	196	4	5	0	1610	38	1710	41	18.	0.4	39.6	0.95	2
414429	D	4	6.4	800	7	0	34	0	375	4	440	5	2.	0.0	12.2	0.15	1
414430	D	4	6.2	950	5	0	30	0	480	11	530	12	6.	0.2	15.6	0.33	2
414431	D	1	3.8	725	65	0	0	0	296	0	380	0	0.	0.0	5.0	0.00	0
414432	D	1	3.7	800	129	0	0	0	282	0	400	0	1.	0.0	6.8	0.00	0
414433	D	4	5.8	470	0	0	16	0	280	6	245	5	1.	0.0	1.6	0.04	2
414434	D	1	6.4	1350	0	0	61	0	715	0	750	0	0.	0.0	0.0	0.00	0
484435	D	4	6.6	1400	5	0	43	5	750	90	780	93	5.	0.6	12.3	1.48	10
414436	D	4	6.6	1650	118	5	76	3	960	46	1000	49	22.	1.1	19.6	0.94	4
414437	D	4	4.6	1275	178	12	0	0	585	42	795	57	35.	2.5	3.6	0.26	6
414438	D	4	3.7	3300	380	9	0	0	1940	46	2200	52	9.	0.2	47.2	1.13	2
414439	D	4	3.8	1400	212	5	0	0	800	19	810	19	6.	0.1	16.1	0.39	2
414440	D	4	5.0	65	34	0	2	0	12	0	20	0	0.	0.0	0.2	0.00	1
414441	D	4	3.3	2000	505	6	0	0	1070	12	1350	16	15.	0.2	21.5	0.26	1
414442	D	1	4.2	2000	145	0	0	0	1145	0	1300	0	3.	0.0	37.5	0.00	0
414443	D	4	4.2	3000	177	2	0	0	1760	21	1960	23	18.	0.2	51.8	0.62	1
414444	D	4	3.8	2400	144	1	0	0	1390	16	1680	20	6.	0.1	50.4	0.40	1
414445	D	1	0.0	1450	131	0	0	0	625	0	840	0	4.	0.0	14.4	0.00	0
414451	D	6	3.5	1050	175	0	0	0	380	0	590	0	1.	0.0	10.2	0.00	0
414452	C	6	3.6	1300	200	2	0	0	440	5	660	7	12.	0.1	10.8	0.13	1
414453	C	6	4.0	1600	255	24	0	0	675	64	980	94	13.	1.2	16.0	1.54	8
414454	D	1	2.1	2200	325	3	0	0	905	10	1175	14	11.	0.1	13.0	0.16	1

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LICKING CREEK, PENNSYLVANIA - CLARION COUNTY

LICKING CREEK, PENNSYLVANIA - CLARION COUNTY												
MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM	
414455	D	1	3.1	1200	290	0	0	0	69.	0.0	0.00	0
414456	D	1	2.6	2600	475	5	0	7	2.	0.0	0.04	1
414457	D	2	6.9	800	29	0	14	0	0.	0.0	0.00	0
414458	D	2	3.4	1550	445	5	0	5	18.	0.2	0.08	1
414459	D	2	3.6	1100	190	0	0	0	1.	0.0	0.00	0
414460	D	7	5.0	500	74	0	3	0	0.	0.0	0.02	1
414461	D	7	3.9	510	144	1	0	4	1.	0.0	0.03	1
414462	D	8	3.6	875	310	3	0	1	2.	0.0	0.08	1
414463	D	7	3.1	400	130	1	0	1	2.	0.0	0.03	1
414464	D	7	3.7	408	148	7	0	7	0.	0.0	0.11	4
414465	D	2	6.6	650	44	1	6	8	0.	0.0	0.00	2
414466	D	8	3.4	2200	725	0	0	0	7.	0.0	0.00	0
414467	D	8	3.1	3500	1710	0	0	0	3.	0.0	0.00	0
414468	D	2	3.3	1090	440	21	0	9	1.	0.0	0.48	4
414469	D	8	3.1	1400	430	5	0	3	0.	0.0	0.21	1
414470	D	2	4.3	850	245	2	0	2	3.	0.0	0.11	1
414471	D	8	3.5	775	220	31	0	27	1.	0.2	0.95	12
414472	D	8	3.9	675	160	0	0	0	0.	0.0	0.00	0
414473	D	8	3.4	900	300	0	0	0	0.	0.0	0.00	0
414474	D	8	6.7	685	54	1	38	6	4.	0.1	0.08	2
414475	D	4	4.8	650	56	0	3	0	0.	0.0	0.00	0
414476	E	4	3.1	1950	365	372	0	0	13.	13.3	15.0	85
414477	E	4	3.3	2100	440	448	0	0	115.	117.3	10.5	85
414478	D	4	3.9	1200	190	22	0	0	26.	3.1	3.6	10

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LICKING CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACTIVITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM					
414479	C	4	0.0	1050	180	4	0	625	15	470	11	16.	0.4	3.0	0.07	2
414480	D	6	2.6	750	200	0	0	95	0	250	0	2.	0.0	4.6	0.00	0
414481	D	6	3.3	1800	580	69	0	550	66	1050	126	2.	0.2	28.5	3.42	10
414482	C	5	2.7	2600	1345	16	0	270	3	1365	16	238.	2.9	9.4	0.11	1
414483	D	5	4.1	1200	340	4	0	440	5	585	7	3.	0.0	7.5	0.09	1
414484	C	5	2.9	2900	880	52	0	1000	60	1645	98	4.	0.2	49.7	2.98	5
414485	D	5	3.3	3600	1425	427	0	1285	385	2430	729	167.	50.0	86.4	25.92	25
414486	D	5	6.4	1550	22	23	50	760	820	640	691	7.	7.3	10.0	10.80	90
414487	C	5	2.9	5500	3270	78	0	1435	34	4725	113	81.	1.9	99.9	2.40	2
414488	D	5	6.4	4000	2075	24	52	848	10	2600	31	7.	0.1	91.0	1.09	1
414489	D	5	3.6	5000	2730	32	0	1150	13	4140	49	2.	0.0	70.8	0.85	1
414490	D	5	3.2	7000	4140	49	0	2380	28	6200	74	650.	7.6	99.9	1.20	1
414491	B	5	4.4	6500	4635	667	0	1280	184	5775	831	1225.	176.4	99.9	14.39	12
414492	D	1	3.4	900	250	0	0	110	0	300	0	3.	0.0	10.0	0.00	0
414493	D	8	3.5	925	210	2	0	244	2	420	5	3.	0.0	6.8	0.08	1
414494	D	7	3.9	1600	525	18	0	482	17	1000	36	2.	0.1	23.6	0.85	3
414495	D	7	4.0	900	140	8	0	324	19	460	27	1.	0.1	7.2	0.43	5
414496	D	9	2.8	2200	870	0	0	106	0	975	0	31.	0.0	7.5	0.00	0
414497	D	7	3.0	2700	755	54	0	950	68	1750	126	9.	0.7	23.1	1.66	6
414498	D	8	3.1	2700	500	18	0	1330	47	1820	65	6.	0.2	18.2	0.66	3
414499	D	8	3.0	1800	465	5	0	585	7	1000	12	4.	0.0	26.5	0.32	1
414534	D	8	3.7	1000	290	10	0	204	7	470	16	3.	0.1	8.0	0.29	3
414535	D	8	3.5	98	150	0	0	67	0	150	0	0.	0.0	2.9	0.00	0
414536	D	8	3.5	460	183	2	0	140	1	340	4	10.	0.1	4.0	0.05	1

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LICKING CREEK, PENNSYLVANIA - CLARION COUNTY

CLICKING CREEK, PENNSYLVANIA - CLARION COUNTY																	
MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
414537	D	2	4.6	2300	250	27	1	0	866	93	1200	129	6.	0.6	37.2	4.02	9
414538	D	4	4.8	700	64	0	0	0	446	0	440	0	1.	0.0	2.2	0.00	0
414550	D	7	3.5	350	145	3	0	0	48	1	125	3	1.	0.0	2.4	0.06	2
414551	D	7	3.2	1150	280	3	0	0	222	2	480	5	9.	0.1	7.5	0.09	1
414552	D	7	3.4	2200	545	78	0	0	880	126	1600	230	2.	0.3	43.5	6.26	12
414554	D	8	3.2	3900	910	0	0	0	2400	0	2550	0	21.	0.0	48.0	0.00	0
414555	D	8	3.4	3300	910	0	0	0	1480	0	2080	0	22.	0.0	32.8	0.00	0
414556	D	8	3.3	1100	285	0	0	0	125	0	345	0	8.	0.0	3.0	0.00	0
414557	D	8	3.2	500	125	0	0	0	62	0	170	0	1.	0.0	3.5	0.00	0
414558	D	8	3.0	2300	810	0	0	0	147	0	900	0	105.	0.0	4.2	0.00	0
414559	E	7	3.5	2800	820	9	0	0	725	8	1785	21	120.	1.4	23.8	0.29	1
414560	D	8	3.0	1400	500	0	0	0	220	0	720	0	17.	0.0	9.3	0.00	0
414561	D	8	3.3	1700	705	25	0	0	212	7	700	25	16.	0.6	10.8	0.39	3
414562	D	8	3.3	2200	695	16	0	0	552	13	1290	30	43.	1.0	40.8	0.98	2
414563	D	7	2.9	2200	515	30	0	0	290	17	690	41	10.	0.6	15.0	0.90	5
414564	D	7	2.9	3600	1610	154	0	0	895	85	2500	240	180.	17.3	52.0	4.99	8
414565	D	8	3.3	3000	515	61	0	0	1750	210	1960	235	10.	1.2	39.2	4.70	10
414566	C	10	3.9	1900	470	197	0	0	715	300	1100	462	14.	5.7	20.5	8.61	35
414567	C	9	3.0	2800	970	349	0	0	800	288	1785	642	18.	6.6	28.0	10.08	30
414568	C	9	3.0	3000	1295	233	0	0	725	130	1760	316	52.	9.4	36.0	6.48	15
414569	C	9	3.0	5000	1975	71	0	0	1390	50	4500	162	13.	0.5	99.9	3.40	3
414570	C	9	3.0	1600	445	117	0	0	455	120	880	232	7.	1.6	13.2	3.48	22
414571	E	9	3.3	1600	420	45	0	0	492	53	900	97	30.	3.2	26.0	2.81	9
414572	D	9	3.5	6000	3320	199	0	0	1430	85	7250	435	685.	41.1	99.9	5.99	5

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LICKING CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM					
414576	C	12	3.6	1550	315	26	0	635	53	780	65	24.	2.0	9.2	0.77	7
414577	D	12	3.3	1800	605	14	0	380	9	650	15	9.	0.2	21.5	0.52	2
414578	D	12	2.8	2100	710	8	0	456	5	1075	12	14.	0.2	24.5	0.29	1
414579	D	12	3.3	1450	525	0	0	440	0	780	0	2.	0.0	20.4	0.00	0
414580	E	12	3.1	975	235	5	0	244	5	450	10	3.	0.1	7.4	0.18	2
414582	E	2	2.5	4500	1990	23	0	775	9	3720	44	56.	0.7	99.9	1.20	1
414583	D	2	3.0	2600	685	24	0	1170	42	1540	55	25.	0.9	42.0	1.51	3
414589	A	0	2.7	3000	570	4062	0	210	1496	1720	12260	116.	826.8	44.0	313.63	594
414590	A	0	2.6	3250	880	3706	0	1144	4818	1872	7884	139.	586.3	42.4	178.59	351
414591	A	0	3.2	1750	470	1347	0	820	2351	1400	4015	13.	36.7	34.4	98.66	239
414592	A	0	3.5	1500	260	5307	4	616	12573	624	12737	6.	130.6	10.8	220.45	1701
414593	A	0	2.6	2200	355	18999	0	760	40675	990	52984	15.	802.8	21.6	1156.03	4460
414595	A	0	6.4	970	0	0	48	430	3908	300	2689	2.	14.3	5.6	50.20	747
414599	D	7	3.2	6000	2525	242	0	2420	232	7125	684	90.	8.6	99.9	9.59	8
414600	A	0	6.9	1800	575	138	0	1090	261	1525	366	40.	9.5	34.0	8.16	20

APPENDIX E

MILL CREEK WATERSHED
MINE DRAINAGE DATACODES FOR TABULAR DATA

<u>TYPE</u>	<u>RECEIVING STREAM</u>
A - Streams	1 - Mill Creek
B - Gas Well	2 - Tribs to Mill Creek
D - Strip Mine	3 - Little Mill Creek
* - Spring	4 - Tribs to Little Mill Creek
** - Unknown	5 - Jones Run
	6 - Douglas Run
	7 - Whites Run

MILL COFFEE WATERSHED - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM							
414240	D	6	2.8	1500	895	10	0	121	1	930	11	47.	0.6	15.6	0.19	1	
414241	D	4	3.3	775	130	0	0	188	0	370	0	1.	0.0	6.2	0.00	0	
414242	D	4	4.0	2800	883	317	0	408	146	2205	793	5.	1.8	55.3	19.91	30	
414243	D	4	5.5	650	75	2	12	0	229	8	290	10	1.	0.0	26.0	0.94	3
414244	D	4	3.9	800	130	0	0	235	0	390	0	0.	0.0	20.0	0.00	0	
414245	D	4	5.0	170	4	0	19	0	56	0	40	0	1.	0.0	0.5	0.00	0
414246	D	4	4.7	100	60	0	2	0	38	0	25	0	0.	0.0	0.6	0.00	0
414247	B	1	5.2	220	0	0	40	2	51	3	55	3	16.	1.0	1.2	0.07	5
414248	D	6	3.0	1300	500	30	0	480	28	680	40	15.	0.9	14.4	0.86	5	
414249	D	6	3.2	1500	555	13	0	182	4	760	18	11.	0.3	15.6	0.37	2	
414252	**	1	3.0	1250	138	8	0	528	31	735	44	12.	0.7	13.5	0.81	5	
414284	D	4	3.2	5000	3740	4263	0	1700	1938	4700	5358	445.	507.3	73.5	83.79	95	
414350	D	5	2.7	2800	1635	39	0	440	10	2065	49	67.	1.6	77.0	1.85	2	
414351	D	5	3.2	925	230	22	0	210	20	450	43	25.	2.4	13.6	1.31	8	
414352	D	5	3.5	1600	1110	93	0	158	13	1300	109	3.	0.3	30.4	2.55	7	
414353	D	5	3.4	2000	1040	0	0	194	0	1375	0	8.	0.0	59.0	0.00	0	
414354	D	7	3.6	250	20	0	0	30	1	55	2	1.	0.0	1.1	0.05	4	
414355	D	5	3.2	3000	1765	42	0	270	6	2205	52	85.	2.0	68.6	1.65	2	
414356	D	5	3.4	2800	1260	907	0	485	349	1960	1411	41.	29.2	93.1	67.03	60	
414357	D	5	3.4	2000	930	892	0	525	504	1325	1272	33.	31.2	43.0	41.28	80	
414358	*	5	3.6	1900	615	14	0	480	11	1325	31	88.	2.1	60.0	1.44	2	
414359	D	2	3.4	790	280	0	0	67	0	290	0	3.	0.0	9.8	0.00	0	
414360	**	2	3.4	1200	200	144	0	395	284	660	475	8.	5.6	12.9	9.29	60	
414361	B	5	3.1	2400	750	36	0	700	33	1560	74	188.	9.0	42.6	2.04	4	

MILL CREEK WATERSHED - CLARION COUNTY											
MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM
414362	D	4	7.6	160	43	0	56	0	50	0	0
414363	D	4	5.5	140	39	0	32	0	35	0	0
414364	D	4	4.1	140	65	0	38	0	40	0	1
414365	D	4	5.6	50	25	0	15	0	10	0	0
414366	D	4	4.0	620	154	74	228	109	350	168	40
414367	D	4	3.5	800	176	0	230	0	450	0	0
414368	B	3	3.2	2200	515	43	736	61	1325	111	7
414372	D	6	3.3	650	270	0	32	0	265	0	0
414446	A	0	4.6	550	64	16657	0	168	43727	235	21690
414447	A	0	5.9	110	2	178	8	714	35	3124	7439
414448	A	0	3.8	1500	420	11566	0	412	11346	960	2295
414449	A	0	3.5	1525	615	11328	0	256	4715	920	1535

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APPENDIX F

PINEY CREEK WATERSHED
MINE DRAINAGE DATA

CODES FOR TABULAR DATA

<u>TYPE</u>	<u>RECEIVING STREAM</u>
A - Streams	1 - Piney Creek
B - Gas Well	2 - Tribs to Piney Creek
C - Drift Mine	3 - Brush Run
D - Strip Mine	4 - Tribs to Brush Run
E - Combination Drift Mine	5 - Gathers Run
F - Combination Strip Mine	6 - Tribs to Gathers Run
G - Coal Washery	7 - Little Piney Creek
J - Active	8 - Tribs to Little Piney Creek
	9 - Tribs to Reids Run
	10 - Tribs to Poe Run
	11 - Glade Run
	12 - Sloan Run
	13 - Tribs to Sloan Run
	14 - Parsons Run

PINEY CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
411111	E	8	3.2	4000	1630	58	0	0	1060	38	3300	118	4.	0.2	99.0	3.56	3
411112	F	4	3.0	3800	1620	19	0	0	766	9	3100	37	8.	0.1	99.9	1.20	1
411113	D	3	2.9	2450	1560	0	0	0	320	0	2220	0	5.	0.0	63.0	0.00	0
411114	C	3	2.8	2000	850	10	0	0	284	3	1450	17	5.	0.1	54.0	0.65	1
411115	D	3	3.0	1800	590	106	0	0	368	66	1180	212	12.	2.1	66.0	11.88	15
411116	D	4	3.0	2800	800	144	0	0	852	153	2065	371	5.	0.9	84.0	15.12	15
411117	D	3	3.1	2200	525	0	0	0	672	0	1375	0	8.	0.0	53.0	0.00	0
411118	D	3	6.1	90	94	0	21	0	68	0	0	0	1.	0.0	0.4	0.00	0
411119	D	4	3.1	3300	1250	30	0	0	772	18	2600	62	12.	0.3	98.9	2.40	2
411120	D	4	3.7	2200	750	9	0	0	490	5	1500	18	85.	1.0	85.0	1.02	1
411121	D	3	3.3	3000	820	590	0	0	948	682	2200	1584	17.	12.4	80.0	57.60	60
411122	D	3	3.2	5500	1355	0	0	0	2532	0	4140	0	14.	0.0	99.9	0.00	0
411123	B	3	3.1	1600	355	4	0	0	402	4	1020	12	7.	0.1	20.6	0.25	1
411124	C	3	2.8	2200	910	10	0	0	288	3	1200	14	119.	1.4	17.5	0.21	1
411125	C	3	3.0	2300	695	150	0	0	314	67	1200	259	14.	2.9	32.0	6.91	18
411126	C	3	3.1	2600	845	60	0	0	424	30	1590	114	31.	2.2	30.0	2.16	6
411127	C	4	3.1	3500	1730	41	0	0	324	7	2655	63	92.	2.2	63.0	1.51	2
411128	D	4	3.6	3600	1295	0	0	0	1000	0	3015	0	4.	0.0	78.0	0.00	0
411129	E	4	3.0	1950	355	852	0	0	782	1876	975	2340	8.	18.0	37.0	88.80	200
411130	D	4	3.8	2250	925	666	0	0	510	367	1650	1188	86.	61.9	55.0	39.60	60
411131	E	4	3.3	1225	35	0	0	0	210	5	660	15	3.	0.1	11.4	0.27	2
411132	D	4	3.7	1175	254	0	0	0	354	0	735	0	2.	0.0	12.8	0.00	0
411133	D	4	3.2	2400	880	0	0	0	222	0	1410	0	0.	0.0	0.0	0.00	0
411134	D	4	3.7	1450	500	0	0	0	152	0	860	0	4.	0.0	28.0	0.00	0

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PINEY CREEK PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM					
411135	C	4	3.2	2400	560	6	0	158	1	810	9	8.	0.1	22.5	0.27	1
411136	D	3	3.6	2800	735	158	0	1320	285	1645	355	68.	14.7	99.9	21.58	18
411137	D	8	3.2	2350	615	0	0	925	0	1410	0	2.	0.0	42.0	0.00	0
411138	D	8	4.2	3000	560	0	0	1455	0	1720	0	2.	0.0	25.6	0.00	0
411139	C	8	3.7	2500	930	334	0	1260	453	2070	745	9.	3.2	99.9	35.96	30
411140	D	4	3.3	4000	1900	0	0	1090	0	2700	0	80.	0.0	95.0	0.00	0
411141	D	3	4.3	4000	1185	426	0	1780	640	3070	1105	13.	4.5	99.9	35.96	30
411142	C	4	3.5	1300	405	72	0	246	44	690	124	5.	0.8	17.4	3.13	15
411143	C	4	3.6	1900	750	135	0	380	68	1150	207	3.	0.6	50.0	9.00	15
411144	C	4	3.7	1350	485	174	0	337	121	900	324	14.	4.9	33.0	11.88	30
411145	D	3	3.7	1050	225	8	0	230	8	570	20	7.	0.2	13.2	0.48	3
411146	D	4	3.5	2600	900	64	0	930	66	1820	131	6.	0.4	84.0	6.05	6
411147	D	4	3.5	750	155	0	0	159	0	330	0	1.	0.0	9.8	0.00	0
411148	D	4	3.3	2000	475	0	0	610	0	1175	0	24.	0.0	40.0	0.00	0
411149	D	4	3.5	1300	350	126	0	500	180	840	302	7.	2.6	33.6	12.10	30
411157	DJ	1	6.3	1600	230	289	6	1392	1753	2040	2570	7.	8.4	54.4	68.54	105
411158	D	1	3.5	2200	1015	60	0	872	52	2350	141	11.	0.7	77.0	4.62	5
411159	D	1	3.7	1500	502	72	0	992	142	1275	183	28.	4.1	52.2	7.52	12
411160	D	2	4.1	3800	505	42	0	1300	109	2550	214	3.	0.2	74.0	6.22	7
411161	E	7	5.6	2750	770	534	0	950	684	2100	1512	112.	80.6	99.9	71.93	60
411163	E	7	3.0	5000	2070	471	0	1456	331	3780	861	114.	26.0	87.0	19.84	19
411164	D	8	3.2	1800	575	20	0	390	14	1100	39	10.	0.4	42.0	1.51	3
411165	D	2	3.3	2400	790	142	0	698	125	1860	334	3.	0.5	91.0	16.38	15
411169	D	2	3.5	1050	124	0	0	440	0	530	0	2.	0.0	12.0	0.00	0

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PINEY CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM		
411170	D	2	3.0	840	131	0	0	216	0	390	0	0	
411171	D	2	5.6	2300	245	2	121	1	1224	14	1740	20	0
411172	D	2	5.7	1800	43	1	6	0	1230	29	1200	28	0
411173	D	2	2.9	2140	510	1542	0	0	624	1886	1375	4158	5.
411174	D	2	3.9	3250	1530	0	0	0	632	0	2840	0	4.
411175	D	2	3.8	2600	755	63	0	0	880	73	1830	153	4.
411176	C	2	2.6	1450	555	13	0	0	40	0	620	14	38.
411177	D	2	2.9	6000	2220	0	0	0	2350	0	4875	0	4.
411178	D	2	3.1	1075	320	3	0	0	206	2	540	6	2.
411179	D	2	5.4	70	10	0	15	0	20	0	0	0	0.
411180	D	2	4.3	1300	335	24	0	0	415	29	870	62	1.
411181	C	2	3.5	1200	480	5	0	0	194	2	750	9	47.
411182	B	8	6.2	270	75	2	0	0	60	2	100	3	27.
411183	D	8	4.1	500	175	6	0	0	112	4	240	8	1.
414201	D	4	3.9	1075	275	39	0	0	274	39	560	80	18.
414202	E	4	3.7	1075	320	53	0	0	214	35	530	89	3.
414203	C	3	5.7	300	0	0	17	8	90	43	67	32	3.
414205	D	3	4.0	120	28	0	0	0	25	0	25	0	1.
414206	D	4	3.4	2200	740	0	0	0	82	0	750	0	88.
414207	DJ	1	3.1	8000	11750	141	0	0	4600	55	0	0	1100.
414208	DJ	1	3.2	8000	5965	858	0	0	445	64	6900	993	136.
414209	C	3	2.7	600	135	1	0	0	39	0	155	1	7.
414210	C	3	5.5	1500	170	16	0	0	660	63	940	90	110.

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PINEY CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM					
414211	C	3	3.7	1150	190	6	0	380	13	615	22	20.	0.7	15.3	0.55	3
414212	E	3	3.5	1750	565	27	0	400	19	1020	48	115.	5.5	10.0	0.48	4
414213	C	3	3.5	1100	280	13	0	192	9	504	24	20.	1.0	6.0	0.29	4
414214	C	4	3.8	1600	305	219	0	566	407	900	648	55.	39.7	16.0	11.52	60
414215	D	4	3.2	3800	1410	50	0	980	35	2500	90	41.	1.5	99.9	3.60	3
414216	D	4	4.5	1800	350	756	0	1000	2160	1360	2937	72.	156.4	50.0	108.00	180
414217	D	2	3.9	1900	338	85	0	940	236	1350	340	2.	0.6	40.8	10.28	21
414218	E	4	6.5	2400	305	109	0	1000	360	1320	475	40.	14.4	50.4	18.14	30
414219	C	2	3.0	4500	2795	503	0	277	49	3245	584	465.	83.7	99.9	17.98	15
414220	D	2	3.2	1100	240	0	0	80	0	285	0	15.	0.0	4.8	0.00	0
414221	D	2	2.7	8000	3495	0	0	57	0	3375	0	930.	0.0	8.8	0.00	0
414222	D	2	2.9	1700	650	0	0	67	0	660	0	35.	0.0	7.6	0.00	0
414223	D	2	3.0	1300	320	0	0	57	0	315	0	16.	0.0	5.6	0.00	0
414224	D	3	3.4	1200	275	0	0	175	0	495	0	5.	0.0	13.8	0.00	0
414225	G	1	3.2	3000	1585	19	0	500	6	2360	28	224.	2.7	26.4	0.32	1
414226	D	1	2.6	8000	6655	0	0	47	0	6750	0	1180.	0.0	13.8	0.00	0
414227	D	2	3.3	3600	550	0	0	976	0	2475	0	17.	0.0	53.1	0.00	0
414228	D	9	3.2	8000	1080	0	0	3400	0	4375	0	38.	0.0	99.9	0.00	0
414229	C	2	2.9	1800	695	8	0	160	1	900	10	99.	1.2	5.5	0.07	1
414230	D	5	3.3	1800	415	0	0	500	0	980	0	6.	0.0	24.8	0.00	0
414231	D	5	3.0	700	80	0	0	79	0	160	0	1.	0.0	3.5	0.00	0
414233	D	2	3.1	4000	1550	186	0	1085	130	3250	390	136.	16.3	82.5	9.90	10
414234	D	6	3.0	3300	1580	0	0	177	0	2070	0	86.	0.0	50.8	0.00	0
414235	D	2	3.1	2900	850	0	0	485	0	1540	0	49.	0.0	28.4	0.00	0

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PINEY CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	pH	COND.	ACTIVITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE LB/DAY	FLOW GPM
414236	D	2	3.1	700	200	0	0	160	0	0.0	0
414238	B	1	3.2	1700	220	66	0	355	106	15.6	25
414239	M	3	6.7	925	56	2	3	420	15	4.8	3
414250	D	8	3.5	800	199	2	0	192	2	9.0	1
414251	D	8	2.5	2800	1440	34	0	158	3	17.5	2
414255	D	8	3.0	1800	575	8	0	230	3	34.0	1
414256	D	7	4.1	1100	25	0	0	38	0	0.6	0
414260	C	8	3.5	1325	385	73	0	327	62	19.5	16
414261	D	10	3.5	480	100	0	0	119	0	3.3	0
414262	D	10	5.6	500	5	0	23	226	5	3.0	2
414263	B	2	5.7	950	0	0	70	15	334	2.1	18
414264	D	10	3.4	1700	533	0	0	490	0	72.0	0
414265	D	10	3.9	500	115	0	0	104	0	11.5	0
414266	D	10	3.4	800	130	0	0	232	0	17.5	0
414268	F	11	3.5	6000	3150	37	0	1920	23	99.9	1
414269	E	11	3.1	6000	2200	52	0	2380	57	99.9	2
414270	D	13	3.7	1300	290	3	0	173	2	29.0	1
414271	F	12	4.1	1525	350	25	0	670	48	46.0	6
414272	F	14	3.9	2700	1140	13	0	1440	17	99.9	1
414273	B	8	7.0	600	24	14	20	12	206	2.5	50
414274	D	8	3.3	700	150	3	0	220	5	4.4	2
414275	D	8	2.6	900	300	0	0	40	0	4.2	0
414276	D	8	4.5	75	20	0	1	25	0	0.6	0
414277	A	0	3.2	1025	270	1778	0	178	1172	14.2	549

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PINEY CREEK, PENNSYLVANIA - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
414278	A	0	6.7	680	5	32	10	64	296	1918	310	2008	1.	3.2	10.4	67.39	540
414279	A	0	3.2	1875	430	2997	0	0	696	4852	1280	8924	28.	195.2	42.4	295.61	581
414280	A	0	3.2	875	15	242	0	0	106	1712	260	4199	5.	80.8	22.8	368.27	1346
414281	A	0	3.3	1300	280	5490	0	0	980	19215	700	13725	4.	70.6	22.0	431.38	1634
414282	A	0	4.3	675	93	4118	0	0	217	9608	320	14169	1.	39.9	8.8	389.66	3690
414283	A	0	3.4	875	20	1638	0	0	216	17695	470	38504	3.	262.2	13.6	1114.17	6827

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APPENDIX G

TOBY CREEK WATERSHED
MINE DRAINAGE DATA
(CLARION COUNTY)

CODES FOR TABULAR DATA

TYPE

A - Stream
B - Gas Well
C - Drift Mine
D - Strip Mine

RECEIVING STREAM

1 - Toby Creek
2 - Tribs to Toby Creek
3 - Engle Run
4 - Step Creek
5 - Tribs to Step Creek
6 - Rapp Run

TORY CRK WATERSHED - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACTIVITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON MG/L LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM					
411001	D	2	2.8	370	95	6	0	26	1	105	7	2.	0.2	3.2	0.23	6
411002	D	2	3.6	270	110	6	0	32	1	105	6	2.	0.1	1.2	0.07	5
411003	D	2	2.7	5000	2225	213	0	1305	125	4100	393	11.	1.1	99.9	9.59	8
411004	C	2	4.5	320	145	124	0	60	45	140	105	4.	2.9	2.8	2.12	63
411005	D	2	5.0	280	45	5	0	58	6	115	13	1.	0.1	1.6	0.19	10
411006	D	2	3.7	1050	370	133	0	104	37	580	208	5.	1.8	10.0	3.60	30
411007	B	2	3.7	1250	470	67	0	190	27	780	112	1.	0.2	27.0	3.89	12
411008	C	2	3.0	5000	2180	784	0	1397	502	5000	1800	85.	30.6	99.9	35.96	30
411009	B	2	3.6	1400	485	69	0	230	33	900	129	1.	0.2	26.0	3.74	12
411010	D	2	3.4	2000	845	124	0	252	36	1425	205	10.	1.4	41.0	5.90	12
411011	B	2	6.6	370	0	0	27	16	68	40	90	9.	5.4	0.9	0.54	50
411012	B	2	6.6	370	0	0	34	24	77	55	140	23.	16.6	1.3	0.94	60
411013	C	2	2.9	1400	435	20	0	137	6	645	30	11.	0.5	8.4	0.40	4
411014	C	2	3.4	2600	1125	270	0	408	97	2040	489	3.	0.7	35.7	8.57	20
411015	C	2	3.4	1050	465	1155	10	24	88	218	650	5.	12.4	23.0	57.13	207
411016	B	2	6.2	270	0	0	44	14	48	15	53	5.	1.5	0.6	0.19	27
411017	C	2	3.0	2500	1047	778	0	445	331	1440	1071	11.	8.0	34.2	25.44	62
411018	C	2	2.8	2500	1180	70	0	354	21	1620	97	13.	0.8	34.8	2.09	5
411019	D	2	3.4	3000	1950	140	0	400	28	2480	178	12.	0.8	46.0	3.31	6
411020	D	2	3.4	3000	1265	75	0	512	30	2120	127	12.	0.7	39.6	2.38	5

NOTES

- 1 = TORY CREEK
- 2 = UNNAMED TRIB. TO TORY CR.
- 3 = ENGLE RUN
- 4 = STEP CREEK
- 5 = UNNAMED TRIB. TO STEP CR.
- 6 = RAPP RUN
- A = STREAM
- B = GAS HELL
- C = DRIFT MINE
- D = STRIP MINE

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TORY CREEK WATERSHED - CLARION COUNTY

MINE NO.	TYPE	REC. STRFAM	P4 COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
411022	C	3	2.8	6750	2865	171	0	1930	115	5625	337	62.	3.7	99.9	5.99	5
411023	D	1	2.8	8000	9265	27795	0	900	2700	11750	35250	1250.	3750.0	99.9	299.70	250
411023	D	1	2.7	9000	8330	49980	0	663	3990	10000	60000	638.	3825.0	99.9	599.40	500
411024	C	2	3.1	4000	2280	82	0	576	20	3550	127	11.	0.4	78.0	2.81	3
411025	D	2	2.6	3000	535	64	0	1008	120	1589	190	6.	0.7	17.5	2.10	10
411026	C	2	4.0	300	76	41	0	88	47	100	54	1.	0.7	2.0	1.08	45
411027	D	6	2.8	1900	955	11	0	140	1	1250	15	38.	0.5	38.7	0.46	1
411028	D	6	2.7	7000	5700	136	0	774	18	8125	195	588.	14.1	99.9	2.40	2
411029	D	6	2.8	8250	7600	5472	0	624	449	9750	7020	775.	558.0	99.9	71.93	60
411030	D	6	3.5	1750	645	7	0	99	1	960	11	64.	0.8	26.0	0.31	1
411031	D	6	2.8	7000	6365	4964	0	476	371	7875	6142	363.	282.8	99.9	77.92	65
411032	D	6	2.8	3000	1170	168	0	180	25	1440	207	41.	5.8	38.7	5.57	12
411033	D	1	2.8	5000	3300	475	0	400	57	4000	576	290.	41.8	99.9	14.39	12
411034	D	1	2.9	3600	2235	321	0	344	49	3420	492	95.	13.7	99.9	14.39	12
411035	D	1	3.8	625	105	2	0	116	2	240	5	2.	0.1	4.8	0.12	2
411036	D	1	4.7	650	50	0	1	169	2	270	3	2.	0.0	5.7	0.07	1
411037	B	1	5.3	1000	125	1	0	266	3	460	5	28.	0.3	5.3	0.06	1
411038	D	1	3.1	5000	3510	42	0	504	6	4450	53	120.	1.4	99.9	1.20	1
411039	D	1	3.0	8000	5940	71	0	688	8	8125	97	188.	2.3	99.9	1.20	1
411040	D	2	2.9	6000	6200	4836	0	7600	5928	8125	6337	675.	526.5	99.9	77.92	65
411041	B	2	3.4	3500	1775	511	0	313	90	2475	712	69.	20.0	99.9	28.77	24

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- A = STREAM
 B = GAS WELL
 C = DRIFT MINE
 D = STRIP MINE

TORY CREEK WATERSHED - CLARION COUNTY

MINE NO.	TYPE	PEC. STREAM	PH COND.	ACTIVITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
411042	B	2	3.7	2600	1020	171	0	383	64	1860	312	180.	30.2	69.0	11.59	14
411044	D	2	2.8	8000	7380	3985	0	1032	557	9625	5197	925.	499.5	99.9	53.95	45
411045	D	2	3.1	5000	3685	265	0	672	48	4875	351	195.	14.0	99.9	7.19	6
411046	D	2	3.0	1600	735	105	0	200	28	860	123	10.	1.4	17.0	2.45	12
411047	C	5	3.1	610	100	1	0	25	0	90	1	2.	0.0	0.6	0.01	1
411048	C	5	3.5	775	60	14	0	79	18	120	28	1.	0.3	1.2	0.29	20
411049	C	5	3.0	650	77	11	0	19	2	75	10	3.	0.4	0.3	0.04	12
411050	B	4	2.8	2800	495	71	0	479	68	1150	165	138.	19.8	10.5	1.51	12
411051	D	2	3.2	1300	453	195	0	148	63	560	241	7.	2.9	18.0	7.78	36
411052	B	4	5.2	1600	355	383	0	446	481	960	1036	160.	172.8	8.0	8.64	90
411053	C	5	3.2	1400	650	23	0	194	6	810	29	6.	0.2	10.4	0.37	3
411054	C	4	2.5	3500	1835	44	0	99	2	2070	49	360.	8.6	8.6	0.21	2
411055	D	2	3.2	1020	335	361	0	64	69	440	475	24.	25.9	4.3	4.64	90
411056	D	2	3.0	1200	385	55	0	127	18	520	74	2.	0.3	12.3	1.77	12
411057	D	2	4.1	2200	1225	88	0	1032	74	2500	180	2.	0.1	87.5	6.30	6
411058	D	2	2.5	3000	3890	2100	0	468	252	6400	3456	368.	198.5	99.9	53.95	45
411059	C	2	4.0	320	1220	14	0	54	0	67	0	1.	0.0	0.8	0.01	1
411060	D	3	2.8	4800	1770	127	0	1276	91	342	24	30.	2.2	69.6	5.01	6
411061	D	3	3.2	1275	525	12	0	99	2	579	13	2.	0.0	8.2	0.20	2
411062	D	1	2.9	2050	915	109	0	186	22	1335	160	19.	2.2	29.0	3.48	10
411063	D	1	3.3	1600	330	47	0	436	62	692	99	8.	1.2	13.2	1.90	12

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TOBY CREEK WATERSHED - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACIDITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESF MG/L LB/DAY	FLOW GPM						
411064	B	3	3.1	1700	250	3	0	0	452	5	588	7	10.	0.1	8.4	0.10	1
411065	C	3	2.9	2800	1150	13	0	0	148	2	1350	16	84.	1.0	11.2	0.13	1
411066	D	1	7.3	2200	25	18	135	97	510	367	1615	1162	3.	2.2	13.2	9.50	60
411067	C	4	2.5	3500	1705	122	0	0	830	59	3087	222	108.	7.8	40.9	2.94	6
411100	D	2	3.4	4000	915	10	0	0	2110	25	3400	40	45.	0.5	98.0	1.18	1
411101	D	4	2.7	4000	1970	23	0	0	740	8	3150	37	51.	0.6	63.5	0.76	1
411102	C	5	3.4	2200	530	101	0	0	660	126	1325	254	23.	4.4	15.7	3.01	16
411103	D	4	3.1	2800	735	8	0	0	635	7	1715	20	19.	0.2	16.2	0.19	1
411104	C	2	3.2	3500	1835	132	0	0	515	37	2960	213	200.	14.4	25.6	1.84	6
411105	C	5	3.2	620	301	0	0	0	36	0	180	0	3.	0.0	1.9	0.00	0
411106	C	4	2.5	1900	840	40	0	0	161	7	1190	57	55.	2.6	3.2	0.15	4
411107	D	4	2.8	2050	1300	62	0	0	312	14	1800	86	350.	16.8	16.5	0.79	4
411108	D	4	4.0	400	620	0	0	0	62	0	67	0	1.	0.0	1.3	0.00	0
411110	C	5	2.9	2900	1145	97	0	0	148	15	1729	145	300.	25.2	8.6	0.72	7
411150	D	2	2.8	6000	2445	29	0	0	1910	22	5145	61	71.	0.8	99.9	1.20	1
411151	D	2	3.2	4500	1270	278	0	0	2310	415	3800	684	110.	19.8	99.9	17.98	15
411152	D	2	2.8	4000	1470	264	0	0	955	171	2830	509	26.	4.7	78.0	14.04	15
411153	C	2	3.6	4200	1310	31	0	0	1596	38	3240	78	2.	0.0	83.0	1.99	2
411154	C	2	3.0	3800	1615	38	0	0	576	13	273	6	23.	0.6	83.0	1.99	2
411155	B	2	2.9	2700	925	33	0	0	428	15	1645	59	200.	7.2	17.5	0.63	3

NOTES :

- 1 = TOBY CREEK
- 2 = UNNAMED TRIB. TO TOBY CR.
- 3 = ENGLE RUN
- 4 = STEP CREEK
- 5 = UNNAMED TRIB. TO STEP CR.
- 6 = RAPP RUN
- A = STREAM
- B = GAS WEL
- C = DRIFT WINE
- D = STRIP WINE

G-5

G-6

TOBY CREEK WATERSHED - CLARION COUNTY

MINE NO.	TYPE	REC. STREAM	PH	COND.	ACTIVITY MG/L LB/DAY	ALKALINITY MG/L LB/DAY	HARDNESS MG/L LB/DAY	SULFATES MG/L LB/DAY	TOT. IRON LB/DAY	MANGANESE MG/L LB/DAY	FLOW GPM						
411162	A	0	3.2	1800	735	34689	0	0	198	9344	1240	58523	18.	868.4	44.0	2076.62	3933
411166	A	0	3.5	625	123	2411	0	0	138	2705	245	4803	2.	33.3	5.4	105.88	1634
411167	A	0	2.7	1450	375	1764	0	0	142	667	680	3198	18.	84.7	7.4	34.81	392
411168	A	0	2.5	5000	3515	2087	0	0	342	203	4380	2601	159.	94.4	99.9	59.34	49
414257	B	1	6.6	2150	425	183	0	0	820	354	1375	594	183.	78.8	25.0	10.80	36
414258	B	1	6.7	625	54	1	0	0	12	0	280	10	27.	1.0	2.4	0.09	3
414508	A	0	3.1	1600	430	18926	0	0	284	12500	780	34332	8.	369.7	18.8	827.50	3668

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- A = STREAM
 R = GAS WELL
 C = DRIFT MINE
 N = STRIP MINE